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PAPERS AND PROCEEDINGS

OF

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The Royal Society of Tasmania

Volume 100

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Royal Society of Tasmania

Papers and Proceedings Volume 100

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Royal Society of Tasmania

Annual Report for the year 1965

The Council submits to members the following report on the activities for the year 1965.

The first meeting of the year was the Annual General Meeting held in March. The report and statement of accounts for 1964 were presented and were adopted. Nominations for the positions of Vice-President and members of Council were received and as no election was required the persons nominated were elected.

Vice-President—Professor G. C. Wade.

Members of Council—Professor I. H. Smith and Dr. W. W. Wilson.

The following were re-elected:—

Hon. Secretary—Dr. W. Bryden.

Hon. Treasurer—Mr. G. E. A. Hale.

Hon. Auditor—Mr. A. M. Hewer.

After the formal business was concluded some selected scientific films were shown.

Council.

During the year four meetings of Council were held in addition to one held in Launceston when members of the Northern Branch Council were able to meet Council members and discuss matters of common interest.

General Meetings.

Eight general meetings were held during the year and after conducting necessary business, a lecture was delivered by a guest speaker, followed by general discussion. The following addresses were given:—

April: Mr. L. A. Endersbee, Hydro-Electric Commission, on "*Thailand and the Lower Mekong project of South-East Asia*".

May: Mr. Keith Taylor, Principal Research Scientist, C.S.I.R.O., Hobart, on "*The Status of the Sirex Wasp and its parasites in Australia and Overseas*".

June: Professor C. H. Barnett, Department of Anatomy, University of Tasmania, on "*The Human Foot*".

July: Mr. V. R. Long, Director of Education, Tasmania, on "*Developments in the Field of Education*".

August: Dr. W. W. Wilson, on "*Early Colonial Medicine*".

September: Mr. W. C. Wentworth, M.H.R., of New South Wales, on "*Nuclear Power for Australia*".

October: Mr. D. D. Lynch, Chairman, Inland Fisheries Commission, on "*A Fish Policy for Tasmania*".

November: Mr. A. M. Olsen, Harvesting Manager, Alginates (Australia) Pty. Ltd., on "*Brown Seaweeds and their Utilisation*".

Papers and Proceedings.

Volume 99 of the "Papers and Proceedings of the Royal Society of Tasmania" was published and distributed to members and to exchange libraries. This is the chief medium by which the series of periodicals in the Society's library is built up. The library itself is a very valuable section of the Royal Society of Tasmania, having a wide range of historical (Tasmanian), scientific and other publications.

As a result of exchanges, purchases, &c., the number of volumes in the library has increased by 310 volumes.

Each year greater use is made of the library by research workers in various States of the Commonwealth as well as by many Tasmanian members who are pursuing special individual studies.

Northern Branch.

The Northern Branch, centered in Launceston, was very active with a programme of general meetings and special excursions. Interest in historical matters in the North continues and many members show great enthusiasm for the varied projects on the year's programme.

Membership.

The total membership of the Society stood at 623 at the end of the year. This figure included 4 Honorary Life Members, 34 Life Members, 1 Corresponding Member and 1 Special Member.

Acknowledgments.

Without the help so generously given by many individuals and organisations, the Society could not function as well as it does. The Council is most grateful to the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery, the Queen Victoria Museum and Art Gallery, the Press, the Radio, the Honorary Solicitor and to the many members and individuals outside the Society who have assisted during the year.

Northern Branch

Annual Report, 1965

Arising from the Annual General Meeting of the Northern Branch held on 26th March, 1965, the Branch Council was composed as follows:—

Chairman—Mr. T. E. Burns.
Vice-Chairman—Mr. Justice G. H. Crawford.
Past-Chairman—Mrs. I. J. Mead.
Honorary Secretary and Treasurer—Mr. W. F. Ellis.
Members of Council—Dr. N. Gold, Mr. P. M. Hart, Mr. L. W. P. Reeves, Mr. G. H. Stancombe, Mr. F. L. Sutherland.

Mr. Burns and Mr. Ellis represented the Branch on the General Council of the Society and Mr. Ellis also served on the Standing Committee of the Society. Mr. Justice Crawford continued as the Northern Branch nominee on the Cradle Mountain-Lake St. Clair National Park Board.

Membership.

On 31st December, 1965, the Northern Branch comprised 263 Members, representing an increase of four in the total over the past year.

Activities.

Ten General Meetings were held during the year at which the average attendance was 65. The following papers were read:—

19th February, 1965—Anthropology Films, introduced by Mr. W. F. Ellis.
26th March, 1965—"Trends in Modern Colour Photography" by Mr. H. J. King.
22nd April, 1965—"The Gallipoli Landing" by Mr. F. C. Green, C.B.E., M.C.
21st May, 1965—"Law and the Quest for Certainty" by Hon. Sir Stanley Burbury, K.B.E., LL.B.
25th June, 1965—"The Growth of Libraries in Australia" by Hon. Mr. Justice Crisp, LL.B.
23rd July, 1965—"The Human Foot" by Professor C. H. Barnett, M.B., F.R.C.S.
24th September, 1965—"The History of Dentistry in Tasmania" by Dr. (Dent.) E. F. Marks, B.D.Sc., L.D.S.
22nd October, 1965—"Fifty Years Since Wegener" by Professor S. Warren Carey, D.Sc., M.A.I.M.M.
26th November, 1965—Bacteriology Films, introduced by Mr. R. W. Patterson, B.Sc., F.R.A.C.I.
10th December, 1965—Members' Night:
"Weekend Peak" by Mr. N. R. Harvey.
"Snakes Galore" by Mr. E. Vogelpoel.
"Let's Look at Canberra" by Mr. R. S. Smith.
"Samoan Beauties" by Mr. F. L. Sutherland.
"Mrs. Charlotte Cleveland—An Early Colonial Artist" by Dr. C. Craig.

Excursions.

Four excursions were arranged to areas of scientific or historical interest—

27th February-1st March, 1965—Cradle Mountain.
4th April, 1965—Mole Creek Caves.
27th October, 1965—Department of Agriculture Research Laboratories.
29th November, 1965—Carrick.

Council.

The Council of the Northern Branch met three times during 1965. In addition, it was represented at five meetings of the General Council, of which one was held in Launceston.

Acknowledgments.

The Branch Council records its appreciation of the Launceston City Council for the facilities at the Queen Victoria Museum which have been provided during the year.

Papers and Proceedings of the Royal Society of Tasmania, Volume 100

THE GEOLOGY OF THE TRIAL HARBOUR DISTRICT

By

T. H. Green*

Geophysics Department, Australian National University.

(With 2 plates and 4 text figures.)

ABSTRACT

A Devonian (?) granite complex intrudes Cambrian (?) volcanics, serpentinised dunite (olivine Fo_{94}), and siltstones and quartzites of the Precambrian (?) Oonah Quartzite and Slate and the Silurian Crotty Quartzite and Amber Slate Formations. The general trends of these country rocks are parallel to the granite margins.

The complex is composed of grey, pink and white granites all with the same mineralogical composition (quartz, orthoclase dominant, plagioclase subordinate). The white granite commonly contains tourmaline nodular segregations. Emplacement began with the pink and grey granites, followed closely by the white granite, and finally the intrusion of minor bodies (porphyritic aplite, micro-granite, aplite, pegmatite, quartz-tourmaline dykes, pyroxene dyke). Tourmaline is abundant in the later intrusions and is sometimes accompanied by cassiterite.

INTRODUCTION

This report describes the results of geological mapping in the Trial Harbour district Western Tasmania, culminating in a laboratory investigation of the rock and mineral types of the area. This involved study of the granite types and their interrelationships, and the metamorphic effect of the granite on the country rocks, and in the course of this study X-ray and optical means were used where possible to indicate the compositions of important minerals. This paper deals with the general geology; the metamorphism will be described in another paper.

The accompanying map of the district (fig. 1) is on a scale of 40 chains to the inch. and extends north-west from Trial Harbour as far as South Gap Creek, inland to the Cumberland Lake and the Mayne's Mine and south to the Little Henty River. The geology was plotted on an enlargement of a contour map of the State Aerial Survey, Zeehan Sheet C (40 chains to the inch) (Topographical Series 1st Edition, reference T 40/50c/1).

As it is situated on the coast, in the path of the westerlies, the district is subjected to boisterous weather, with a high rainfall. Vegetation consists mainly of button grass covering the granite, Precambrian (?) and Silurian rocks, but thick rain forest occurs in sheltered valleys and on the slopes of the Heemskirk Range. The dunite supports an open, stunted scrub flora, but the Cambrian (?) volcanics are covered by a luxuriant rain forest. Consequently inland outcrop of the volcanics is poor except for ridges exposed by bush fire and rocks exposed in Pykes' Creek. Pebble outcrop of weathered Precambrian (?) rocks, dunite, Silurian rocks and rounded granite boulders in situ provide suitable means of mapping boundaries of these rock types inland. Vegetation and soil colour changes often can be used as guides to the rock type (e.g., dark red soil on dunite, red soil on Cambrian (?) volcanics, grey soil on Precambrian (?) rocks and granite).

Outcrop along the coast line strip is about 20-100 yds wide and nearly continuous, apart from occasional sandy or pebble beaches, and except for the dunite, the rocks are usually only slightly weathered.

Previous Literature

The earliest literature describing the geology of the Trial Harbour area was concerned with the economic aspects of the tin mineralization accompanying the granite intrusion (Twelvetrees 1900, Waller 1902, Waller and Hogg 1903), but Waterhouse (1916) reported in great detail on both the economic geology and the petrology of the granite types and country rocks. He discussed the metamorphic aureole, placing emphasis on the abundance of calc-silicate rocks, which he believed to be of metamorphic origin. Waterhouse also considered that the igneous rocks all formed part of one major phase of activity beginning with the intrusion of the gabbro-dunite suite and concluding with the granite complex.

In 1962 Blissett briefly described the geology of the area, based mainly on Waterhouse's report, but he also revised the age relationships of the rocks and applied recent stratigraphic terminology considered to be in accord with geological data from other parts of Tasmania.

Additional literature related to the Trial Harbour district involves mineralogical description connected with tin or nickel mineralization (Edwards 1953, Williams 1958).

PHYSIOGRAPHY

The Trial Harbour area consists of two major physiographical units. These are the coastal plain which reaches a width of 1½ miles and follows the north-westerly-south-easterly trend of the coastline and the Heemskirk-Agnew mountain range which forms the north-eastern margin of the area.

* Carried out as part of an Honours course at the University of Tasmania.

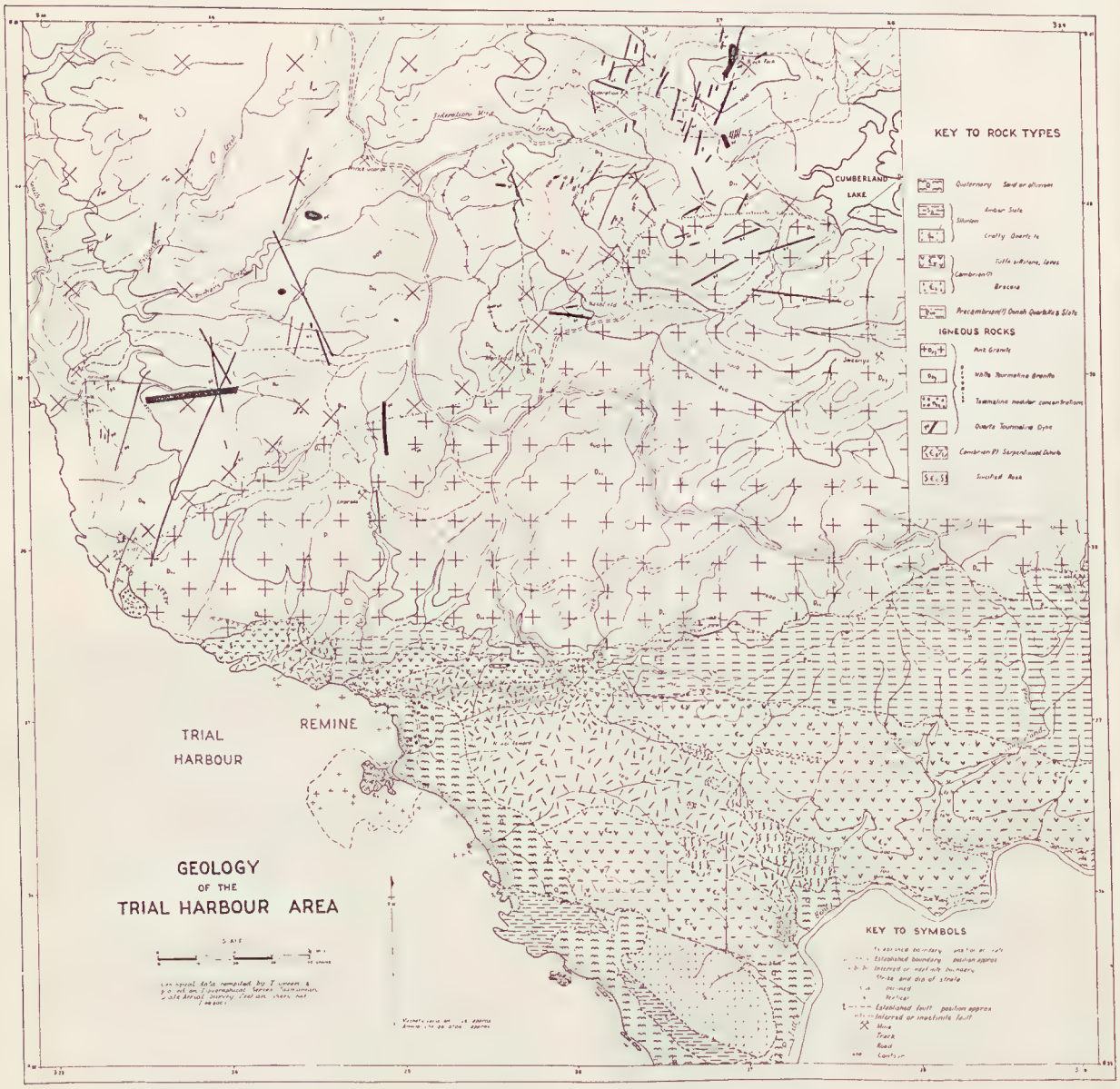


FIG. 1.—Geological Map of the Trial Harbour Area.

The altitude of the coastal plain ranges from about 300′ at the top of the coastline cliffs to 650′ at the base of the Heemskirk Range. This corresponds to the lower coastal surface of Davies (1959). A range of hills between the plain and the main part of the Heemskirk Range has concordant summits 1300′-1600′ high and may be an expression of the higher coastal surface, while the Heemskirk Range (2200′-2500′) possibly reflects the St. Clair surface, with Mt. Agnew (2700′) standing slightly above this level.

Drainage of the area is dominated by the Little Henty River, as its tributaries extend as far north as the Cumberland Dam. The north-western part of the area has a characteristic trellis drainage pattern, governed by jointing in the granite. These streams are short, flowing directly from the Heemskirk Range into the sea. Faulting in the southern part of the area governs the direction of some small streams.

TABLE 1

Summary of the Stratigraphy in the Trial Harbour Area

System	Formation or Rock Type	Thickness (approx.)
4. Quaternary	Dunes, alluvium, gravels	
3. Silurian	Amber Slate	1200′ +
	Crotty Quartzite	1100′ +
2. Cambrian(?)	Siltstones, tuffs or tuffaceous sub-greywackes and tuffaceous siltstones, volcanic breccia lavas	2500′ +
1. Precambrian(?)	Volcanics(?)	2400′ +
	Oonah Quartzite and Slate	

At least two and possibly three old shorelines are evident along the coastline:

(*a*) 12′-18′ above sea level illustrated by concordant topped ridges and benched cliffs 1½ miles north-west of Remine.

(*b*) 25′-30′ above sea level. This is not well developed; slight flattening of seaward slopes occur at this level north-west of Remine and about ⅜ mile south-east of Remine (300 yards inland) a gravel deposit about 30′ above sea level is evident. Pebbles of Owen Conglomerate are present in this gravel.

(*c*) 40′-60′ above sea level reflected by isolated benches north-west of Remine and a possible raised beach dune at the mutton bird rookery one mile north-west of Remine.

Weathering of the granite produces characteristic rounded landforms and frequent isolated tors (e.g., Pulpit Rock).

STRATIGRAPHY

Owing to the limited occurrence of the stratigraphic horizons never far distant from the granite contact, it is difficult to obtain completely unmetamorphosed rocks for comparison with similar sediments from other areas. However the Cambrian(?) volcanic sediments and the Silurian sediments in the southern part of fig. 1 are only slightly metamorphosed.

The thicknesses given are very approximate and were determined assuming no repetition of beds by folding or unobserved faulting.

1. PRECAMBRIAN(?)

Oonah Quartzite and Slate

Rocks of this unit crop out between the granite contact and the Cambrian(?) volcanics and extend in a band from the mouth of Montagu Creek inland with an easterly trend to the eastern limit of the area (see fig. 1) and can be traced continuously to the type area (Blissett 1962, Spry 1958).

In the Trial Harbour area it is composed of interbedded sandstones, sub-greywackes and siltstones. The coarser grained beds range from one inch to several feet in thickness but the siltstones are thinly bedded (¼″-2″). Sandstones grade into sub-greywackes with increasing matrix (sericite) component (e.g. specimens 31922*, 31923, 31924 grade from a recrystallized(?) sandstone containing over 90% quartz such as specimen 31922 to a sub-greywacke such as specimen 31924 containing only about 60% quartz). The normal grainsize of the quartz is 0.2-0.5 mm. but it ranges from 0.01 to 1 mm. so that the sorting is poor. The matrix consists of developing shreds of sericite, and these tend to obscure the margin of the quartz grains. Some quartz may be recrystallized but separate grains in the sericitic matrix are probably relict clastic grains and these vary from sub-angular to sub-rounded, with moderate sphericity.

The siltstones frequently show banding in thin section and usually consist of shred-like sericite with a subordinate quartz component. Quartz grains may reach 0.2 mm. in size (specimens 31925, 31926).

Tourmaline, as pale yellow-brown grains, is a common accessory in the Precambrian(?) rocks.

Quartz and black tourmaline veins commonly cut the Precambrian strata.

Volcanics(?)

Rocks with the appearance of metamorphosed amygdaloidal lavas or "bile-bean" rocks occur in Montagu Creek about 100 yds from the mouth. These rocks, together with thin pale green basic banded rocks, are interbedded with quartzites and slates similar to the Oonah Quartzite and Slate. They occur to the northern (i.e., Precambrian(?)) side of the suspected irregular contact between the Precambrian(?) and Cambrian(?) rocks exposed at the mouth of Montagu Creek (see page 17). Hence they are considered to be Precambrian(?). Similar pale green basic bands have been observed in about the same stratigraphic position relative to the approximate Precambrian(?)/Cambrian(?) boundary further inland.

These rocks could not be obtained unmetamorphosed. They are tentatively considered to be volcanic because of the amygdale-like structures, and the basic composition of the mineral assemblages resulting from metamorphism.

* Numbers refer to the catalogue in the Geology Department, University of Tasmania.

A comparison can be made between these rocks and the Montana Melaphyre Volcanics at Zeehan. Blissett (1962) considers the Montana Volcanics as part of the Oonah Quartzite and Slate. Both these volcanic suites occur near the boundary between Precambrian(?) Oonah Quartzite and Slate and overlying Cambrian(?) formations, but the original definition of the Oonah Formation does not include volcanic rocks (Spry 1958).

2. CAMBRIAN(?)

Volcanic sediments, interbedded lavas and siltstones occur in contact with granite on the coast, are present inland south of the Precambrian(?) rocks and completely surround the serpentinised dunite. In the south-western part of the area Cambrian(?) formations are in faulted contact with Silurian strata.

These formations are termed Cambrian(?) only because of probable similarity with other Tasmanian basic volcanic suites forming part of the Cambrian System (e.g., Waratah, Ulverstone, Smithton and King Island) (Banks 1962). Blissett (1962) records the occurrence of a trilobite on a ridge ½ mile south-east of the Little Henty River and 2 miles south-east of Trial Harbour and correlates the host rock with the Dundas Group. However it is not known whether this trilobite bearing formation is part of the same Cambrian(?) succession as the Trial Harbour volcanic suite and Blissett correlates the Cambrian(?) rocks at Trial Harbour with the Crimson Creek Group. The writer prefers not to attempt such a correlation until more is known about the relative stratigraphic positions of the Oonah Quartzite and Slate, the Crimson Creek Group and the Dundas Group in Western Tasmania and until the nature of the contact between the Oonah Quartzite and Slate and the Cambrian(?) volcanics is resolved (this does not seem possible in the Trial Harbour district) (see p. 17).

(a) Siltstones and Slates

Thinly bedded, laminated, pink siltstones crop out in a road cutting half a mile from Trial Harbour and on the shore platform at the mouth of Montagu Creek. The beds vary from ⅛"-1½" in thickness and are near vertical with a strike of 60°.

Black slates occur near the southern margin of the dunite and in a small cliff above the Little Henty River three-quarters of a mile from the shore-line. They are associated with tuffs and tuffaceous sub-greywackes but form the dominant rock type for about 900' south of the dunite margin and then become subordinate to the coarser sediments which extend to the fault contact with the Silurian strata. In scattered places abundant quartz veining and silicification of the slates has occurred and several prospect trenches have been dug in these localities. These black rocks are distinguishable from the dark fine grained hornfels near the granite and the diopside rock because of a prominent fissility. It is not known whether some of the hornfelses are metamorphic equivalents of these rocks nor can it be determined (without chemical analyses) whether these rocks have a volcanic component and grade into tuffaceous siltstones.

(b) Tuffs

The best outcrops of these rocks in an unmetamorphosed state occur to the south of the Cambrian(?) slates and are in faulted contact with the Crotty Quartzite (fig. 1). Tuffs are also exposed in Pyke's Creek about half a mile from the Little Henty River (specimens 31927, 31928, 31929, 31930, 31931, 31932, 31933).

The rocks vary from dense, dark grey types with occasional white or grey fragments representing chert, quartz or feldspar to pale grey or red-brown (iron stained) types. The fragments range up to 2 cm. in size and are usually sub-angular, but rounded particles are also present (specimen 31931).

An examination of the thin sections shows that these rocks are composed of 60-85% irresolvable matrix and 10-40% clastic quartz, feldspar and rock fragments. Specimen 31928 is slightly metamorphosed and biotite, opaques and actinolite can be identified in the matrix. The matrix of all these rocks is probably volcanic in origin (although without analyses this is uncertain) so that the rocks are termed tuffs, with a subordinate clastic non-volcanic component (non-volcanic quartz and composite quartz fragments). Since specimen 31933 is composed of about 25% lithic fragments it is more accurately termed a lithic tuff. Thin bands of opaques or thin bands of the irresolvable material are frequently visible in the groundmass of the slides (e.g., 31933, 31929).

Quartz varies from 10-30% of the rock and has a grainsize from minute to 1 mm. It occurs as discrete crystals or composite quartz fragments of chert or quartzite, which show microsuturing and undulose extinction of their component grains. The rock fragments have moderate sphericity and are sub-angular-sub-rounded. Two types of single quartz crystals are evident—

(*a*) grains with straight margins apart from marked embayments, sometimes occurring as rhombs or hexagonal prisms (specimen 31928). These represent quartz of volcanic origin, have varying sphericity and are usually angular.

(*b*) grains which are rounded and have moderate-high sphericity. These two types suggest a bimodal origin for the quartz—some from from a volcanic region and some derived from a sedimentary or metamorphic source.

Plagioclase is evident as sub-angular grains up to 0.8 mm. in size and it has moderate sphericity. Its composition cannot be determined reliably but it is probably andesine. Since the feldspar is no more rounded than the volcanic quartz, it is probable that transport from the volcanic source to the area of deposition was rapid. This is borne out by the ferromagnesian rock fragments which are also sub-angular to sub-rounded, similar to the more resistant volcanic quartz grains. The rock fragments reach 3 mm in size and are composed of aggregates of either amphibole or chlorite crystals. Some show banded structures produced by alignment of opaque minerals. In specimen 31929 rare crystals of possibly detrital pyroxene(?) are evident.

Accessory minerals present in the tuffs include opaques (magnetite, pyrite and ilmenite), rutile, apatite and tourmaline.

Some suggestions regarding the possible origin of these rocks can be made from the foregoing observations. The volcanic components of the sediments were transported rapidly from the volcanic source area to a nearby depositional environment where they were deposited after little or no reworking. Fine volcanic dust, larger volcanic lithic fragments, feldspar, volcanic quartz and opaque minerals were intermixed with no apparent sorting. Quartz grains and composite quartz fragments derived from a reworked sedimentary or a metamorphic source area were also carried into the depositional environment and mixed with the volcanic components. The flow-type structures of opaques and sometimes the irresolvable matrix may have developed as the result of movement of the fine grained material during consolidation.

(e) Breccia

A breccia bed 60' wide crops out in thick scrub 1¼ miles east of Remine (see fig. 1). It cannot be traced for more than about a quarter of a mile.

It is poorly sorted, consisting of angular-rounded fragments from 1 mm.-5 cm. in size set in a green (actinolitic) matrix (specimen 31934). The matrix comprises 50-60% of the rock. The rock has an open framework and the fragments have a low sphericity. Most of these fragments are quartz or chert but actinolite, and one case granitic, fragments have been observed. The rock has been metamorphosed and the development of the actinolite matrix suggests that the original sediment had a considerable basic volcanic component, so that it could be termed a volcanic breccia, although portions of the bed occur which have a sand or silt-rich matrix. Graded bedding is evident, suggesting that the top of the near vertical breccia bed is to the south. The different proportions of actinolitic and silt matrix probably reflect variations in the amount of volcanic activity in the depositional area.

(d) Lavas

Bodies, possibly interbedded lava flows, occur in the Cambrian(?) volcanics on the shoreline near the mouth of Montagu Creek (see p. 6).

3. SILURIAN

Silurian rocks are exposed in the south-western corner of the area, where a hill of Crotty Quartzite occurs and Amber Slate crops out on the shoreline from ½-1½ miles south of Remine.

Crotty Quartzite Specimen 31936

This formation is composed mainly of massively bedded pale grey pebbly sandstone but purple sandstones also occur (specimen 31935). This sandstone is very well sorted (quartz grains range from 0.1-0.8 mm. in size). The larger quartz grains tend to be well rounded with a moderate to high sphericity, but the small grains are usually sub-angular to sub-rounded with a low to moderate sphericity. A few grains are composite with undulose extinction suggesting a metamorphic origin. Minor muscovite and accessory apatite, zircon, tourmaline and opaque minerals are also evident.

The pebbles in the grey pebbly sandstone are usually sub-rounded with a moderate sphericity and may reach 1.5 cm. in size. They are enclosed in a sand grade matrix and have an open framework. Rounded depressions common in the rock possibly represent brachiopod moulds. Coarse cross bedding is also evident in this formation.

This formation passes gradually into a series of thinly bedded siltstones which contain *Tentaculites*. The presence of *Tentaculites* suggests that the siltstones belong to the Amber Slate (Blissett 1962) so that the conformably underlying sandstone is the Crotty Quartzite (from the Eldon Group succession defined by Gill and Banks 1950).

Amber Slate

The rocks of this formation strike consistently at 100°-125° and dip steeply both to the north and to the south, although minor folding occurs, especially in the north-western part of the coastline outcrop.

This formation consists of thinly bedded purple brown or grey siltstones, cherty siltstones, calcareous siltstones and more coarsely bedded quartzite. The siltstone beds are usually ½"-3" thick while the quartzite beds reach 12 feet. The quartzites are pale green or yellow and frequently show well developed cross bedding. Lateral variation between quartzite and siltstone may be rapid so that a quartzite bed may change abruptly in thickness or be split into thinner quartzite beds separated by siltstone horizons. In spite of this variation, the quartzites, especially those with cross bedding, provide useful marker horizons along the coast. Some of the coarser calc-silicate bands can also be used as marker beds.

Metamorphism by the granite has resulted in baking of the siltstones and development of calc-silicate hornfels from the calcareous bands. The preferential weathering of the calcareous bands and lenses has given rise to well developed honeycomb weathering.

Fossils are present, but metamorphism has obscured much of the fossil evidence, destroying the finer detail, but strongly ribbed brachiopods, gastropods and crinoid stems are evident. *Tentaculites* is plentiful on some bedding planes.

Sedimentary Structures

Sedimentary structures are common in interbedded coarse and fine siltstones on the coastline outcrop 1 mile south-east of Remine. These structures include scours of coarse siltstone in fine siltstone (plate I, fig. 1), intrastratal flow in coarse siltstone, roll structure of coarse siltstone in fine siltstone, and a "pull-apart" structure.

Two hundred yards north-west of these structures the best developed cross bedding is exposed (plate I, fig. 2) and nearby parallel grooves are evident on the bedding planes of the thinly bedded siltstones. These extend over distances of 50'; the origin of this feature is unknown, but it appears to be a relict lineament accentuated by weathering.

Boudin-like structures consisting of quartzite boudins enclosed in siltstone also occur. It is not certain whether they have a sedimentary or structural origin. The presence of possible ten-

sional cross fractures in the "neck" zone suggests a structural origin.

The truncated current bedding and the scour structures indicate that the beds face to the south-west. Hence the Amber Slate is slightly overturned for the north-western part (about a mile) of the coastal outcrop but swings over to the right-way-up for the south-eastern part (about a third of a mile) of the outcrop. The cross bedding also suggests that the depositional currents giving rise to the cross bedded quartzite came from the south-eastern quadrant.

4. QUATERNARY

The Quaternary System is represented in the area by river alluvium, dunes and gravels. Alluvium ocurs along the margins of the Little Henty River and on marshy flats where small streams flow onto low lying areas behind sand-dunes between Remine and the Little Henty River.

Sand-dunes up to 30' high occur extensively between Remine and the Little Henty River, attaining their maximum development at the northern end of Ocean Beach where they extend inland for about a quarter of a mile.

Gravels are best exposed on the coastline near the mouth of Montagu Creek where a section 8' thick of interbedded fine sands, grit and coarse gravels is present. These are probably deposits from Montagu Creek later eroded by the sea. They are unlike any of the beach deposits now forming.

Serpentine conglomerates, pebbles of serpentinite cemented by iron minerals precipitated from iron-rich solutions derived from the serpentinised dunite, are well exposed on the coastline ¼ mile south of Remine after storms have washed away a beach sand covering. Local development of similar conglomerates is common on the surface of the serpentinised dunite further inland.

IGNEOUS ROCKS

There have been two major phases of igneous activity in the area. These phases and the rocks they produced can be summarised as follows:—

1. Cambrian(?)—
   - (*a*) Basic volcanic rocks (extrusions and a minor intrusion)
   - (*b*) Basic—ultabasic intrusive complex,
2. Devonian—

   Intrusive granitic complex.

Cambrian (?) Igneous Rocks

(a) Volcanic Suite

Dense, black or dark green, crystalline rocks thought to be basic lava flows occur interbedded with thinly bedded siltstones on the shoreline near the mouth of Montagu Creek. The lavas are considered to be Cambrian(?) in age because the host rocks may be correlated on lithological grounds with similar rocks of Cambrian age (page 4).

The basic masses vary from 1' to 6' in thickness. No minerals can be identified in the hand specimen (31980) but a thin section shows that it consists mainly of lath-like feldspar crystals 0.2-0.5 mm. in size and granoblastic pryoxene crystals 0.05-0.1 mm. in size. The presence of lath-like feldspar crystals, in contrast to the usual development of granoblastic feldspar in the metamorphic aureole, suggests an igneous origin for the rock.

Another possible basic mass of igneous origin within the Cambrian sediments occurs on the shoreline near the granite contact north of Remine; it is about 6' wide and traceable for 50'. However, it is entirely recrystallised by thermal metamorphism (except perhaps for a small olivine lens) to basic and ultrabasic hornfelses and no relict igneous textures have been observed, either macro- or microscopically. It appears to cut across banding which is possibly relict bedding in the surrounding hornfels.

A small basic dyke 4" wide is exposed on the shore platform only about 40' from the granite contact. It is not visibly connected with the granite mass and is cut by pyroxene veins. The dyke rock weathers to a red-brown colour but is grey on fresh surfaces. White phenocrysts of plagioclase (Ab_{15}) laths up to 3 mm. in size are present in a metamorphic groundmass mosaic of biotite, hypersthene and opaques (plate I, fig. 3).

(b) Intrusive Suite

This suite is composed of a serpentinised dunite and a hornblende gabbro. The main gabbro mass does not occur within the area mapped (fig. 1) but a brief description is given because of its probable close relationship with the dunite. This gabbro-serpentinised dunite association is similar to basic-ultrabasic complexes described from Bald Hill, Beaconsfield, and Melba Flat-Ring River areas (Twelvetrees 1913, Reid 1923, Taylor 1955, Green 1959 and Blissett 1962).

Because of the similarity in petrology and composition, the basic-ultrabasic associations of intrusive rocks in Tasmania are considered to have originated initially during the same period of igneous activity. Serpentinite-pebble conglomerates in Upper Cambrian rocks at Adamsfield (Carey and Banks 1954) and chromite grains in Lower Ordovician rocks at Queenstown (Wade and Solomon 1958) and Beaconsfield (Green 1959) suggest that the complexes are pre-Ordovician intrusions; and since also they all occur in rocks of Precambrian or Cambrian age (Taylor 1955), the accepted date of intrusion of the ultrabasic-basic rocks of Tasmania is Cambrian. Banks (1962) proposes a Dresbachian age. Tectonic reintrusion of serpentinite acting as a rheid during orogeny could have occurred during the Devonian Tabberabberan Orogeny, subsequent to the initial intrusion, so that ultrabasic intrusives in post-Cambrian rocks are possible. However the dunite at Trial Harbour only occurs in rocks of Cambrian(?) age and does not intrude younger rocks (e.g., Silurian Crotty Quartzite and Amber Slate) so that it is considered to be Cambrian in age.

Serpentinised Dunite

This crops out as low lying reefs backed by small cliffs around Trial Harbour and extends southwards along the coast for half a mile. It occurs intermittently with Cambrian(?) hornfelses for about half a mile north-west of Remine along the

coast, and reaches up to three-quarters of a mile inland. The eastern contact extends as far south as the Little Henty River, following a general south-easterly trend. The northern and part of the southern boundaries follow an east to east-south-east trend inland. Thus the overall shape of the mass, as indicated by the observable margins, is lenticular. The western portion is covered by the sea. Since the length of the body is over four times greater than its width and since the northern and southern contracts are roughly parallel to the strike of the country rocks, while the eastern boundary is discordant, the mass is termed a slightly transgressive sheet.

A diopside rock invariably occurs between the Cambrian(?) hornfelses and the dunite along the northern contact. The southern boundary is poorly exposed but there is no evidence of intervening diopside rock. A direct contact between Cambrian(?) hornfels and dunite was not observed. The southern margins of the dunite show some evidence of shearing, in the form of fine fracturing, but this could not definitely be shown to follow the contact. Some shatter zones probably related to minor faulting are present within the mass, and in one case (spec. 31870) a brecciated serpentine has been cemented by carbonate material. No marginal chilling of the dunite as recorded by Blissett (1962) was observed. The diopside rock obscures possible contact effects of the dunite on the Cambrian(?) rocks; but along the northern contact these Cambrian(?) rocks in contact with the diopside rock are baked and, partially at least, reconstituted. To the south there is some evidence of baking of Cambrian(?) sediments near the serpentinite on the shoreline, but this feature may equally well be attributed to the granite because Silurian sediments to the south are also baked.

The dunite is massive and dark blue when fresh, but weathers to a soft, pale green-brown rock, often with irregular, characteristic resistant crusts, representing magnetite rich patches. Much of the inland surface of the serpentinised dunite is covered by an iron rich gangue, resulting from weathering of abundant magnetite in the mass. Silicified rocks are also common within the dunite.

Small pale-green crystals of olivine with vitreous lustre are occasionally visible with a hand lens in a serpentine-magnetite groundmass. Other minerals visible in the dunite mass are irregular segregations and nodules of magnetite, pholgopite, chlorite, aragonite and antigorite. Veins of fibrous serpentine (chrysotile), magnetite, aragonite, brucite and chalcedony varying from 1 mm. to 10 cm. in size are present. These minerals are probably related to later metamorphism and will be described in detail in another paper. Magnetite is possibly both a primary and secondary mineral. Nickel mineralisation is evident near Remine and heazlewoodite has been identified by X-ray.

Petrography

In thin section the dunite is seen to vary in composition from a rock consisting almost entirely of magnetite and olivine with minor serpentine to one with serpentine, olivine and magnetite, or with serpentine and magnetite or to one of almost pure serpentine. No section was observed which showed any evidence of relict pyroxene, so that the term peridotite cannot be used in the sense that infers the presence of pyroxene (Waterhouse 1916, Blissett 1962, Spry 1962). Since olivine is the only relict mineral observed, the rock is referred to as dunite. The most common serpentine texture is a mesh structure (cf. spec. 31868, 31869) which consists of varying proportions of lizardite, ortho- and clino-chrysotile.

In specimen 31871 olivine occurs as interlocking, anhedral crystals. The larger crystals are extensively fractured and are traversed by irregular magnetite and serpentine veins. In the serpentinised examples (31873, 31874, 31875) olivine consistently has a rounded core-like form, frequently replaced or surrounded by magnetite and a carbonate mineral (probably magnesite). These cores reach 1 mm. in size but several grains separated by serpentine mesh texture are often in optical continuity, indicating that they were once part of a larger crystal. The serpentine mesh consists of ribbons of chrysotile of slightly higher relief and stronger birefringence surrounding and traversing central regions of lizardite, which have lower relief and birefringence than the chrysotile.

Talc, chromite, chlorite are minor minerals present.

A tentative paragenetic sequence for the minerals present in the serpentinised dunite can be given as follows:—

(i) Olivine, magnetite, chromite and primary nickel bearing phases.
(ii) Magnetite veins, serpentine, talc and carbonate minerals.
(iii) Carbonate veins, antigorite, chlorite and minor late-forming lizardite-chrysotile.

The compositions of six olivines from the dunite have been determined in terms of the forsterite-fayalite end members (see table 2, specs. 31871, -74, -75, -78, -79, -73).

TABLE 2

X-ray Determined Composition of Olivines (using Yoder and Sahama's 1957 curve)

Specimen No.	Olivine d_{130}	Composition	Error
31871	2.768	Fo_{97} Fa_3	± 4%
31873	2.769	Fo_{95} Fa_5	± 4%
31874	2.770	Fo_{94} Fa_4	± 4%
31875	2.786	Fo_{70} Fa_{30}	± 4%
31878	2.778	Fo_{82} Fa_{18}	± 4%
31879	2.769	Fo_{95} Fa_5	± 4%

Four of these olivines have a uniformly very high forsterite content indicating that this ultrabasic mass would be classed as an orogenic or alpine type body (cf. Hess 1938, Thayer 1960). However the other two (spec. 31875, 31878) have an anomalously low forsterite content. These anomalous values do not appear to be related to metamorphism by the granite causing possible regeneration of lower temperature more iron-rich olivines, since specimens 31878, 31879 were both obtained near each other and near to the granite contact while specimen 31785 was obtained ½ mile from the granite. In addition to these X-ray determined compositions, a composition of

Fo_{95} Fa_5 was obtained for specimen 31871 from refractive index determinations ($\alpha = 1.650 \pm .004$, $\beta = 1.671 \pm .006$, $\gamma = 1.693 \pm .004$). In this case Deer, Howie and Zussman's (1962) determinative curves were used. Finally, as a further check, analyses of 5 relict olivine cores in specimen 13254 (obtained from a locality close to specimen 31875) were carried out using an ARL electron microprobe. The composition of these grains ranged from Fo_{92} Fa_8 to Fo_{99} Fa_1, with an average composition of Fo_{95} Fa_5. Hence the most probable composition of the olivine in the serpentinised dunite is Fo_{95} Fa_5.

The Origin of the Magnetite

Assuming the primary olivine of the dunite was not zoned with iron rich outer rims surrounding magnesium rich cores, the generally low fayalite content of the relict olivine bears out the proposed occurrence of primary magnetite, since release of iron on serpentinisation of the forsterite rich dunite could not give rise to all the abundant magnetite now present within the ultrabasic mass. This explanation does not agree with results obtained by Bowen and Schairer (1935) for crystallization within the system MgO-FeO-SiO_2. If equilibrium had been maintained throughout, the iron present should have been taken up by crystallization of forsterite-fayalite, rather than crystallization of nearly pure forsterite accompanied by magnetite. If equilibrium was not maintained, then primary crystallization could result in the formation of zoned olivines with forsteritic cores and fayalitic margins. Zoned olivines are frequent in basic volcanic and hypabyssal rocks (Deer, Howie and Zussman 1962, Vol. I p. 23) but the writer has seen no reference to such olivines in dunites.

A second possible alternative if equilibrium was not maintained during the crystallization, is that magmatic segregations of magnetite occurred within the dunitic magma. Later metamorphism by the granite could have then given rise to the present veins and large disseminations of magnetite while the minute disseminated grains may have resulted from the serpentinisation of the olivine. This last suggestion provides the most satisfactory explanation of the observed features of the magnetite and olivine in the serpentinised dunite. Hughes (1958, 1959) has indicated a somewhat similar origin for magnetite deposits in the Tenth Legion and Savage River areas, since he regards these deposits as Cambrian magmatic segregations, but in the case of the Savage River deposits in basic dykes Solomon (1962) favours pre-intrusion concentration and Spry (1962) suggests that the dykes may be older Precambrian.

Origin of the Dunite

The high forsterite content of the olivine indicates that the dunite could be classed as an orogenic-type ultrabasic mass. The contact relationship between the Cambrian(?) country rocks and the dunite are confused by the later metamorphic effects of the granite, so that no statement concerning the origin of the dunite can be made.

Hornblende Gabbro

Hornblende gabbro crops out on the Zeehan-Trial Harbour Road at McIvor Hill about 6 miles from Zeehan. It varies from pale to dark green and from a fine grained interlocking texture of crystals of hornblende and feldspar less than 1 mm. in size, to a coarse grained gabbroic texture with hornblende and feldspar crystals up to 20 mm. in size. Magnetite is present in irregular aggregates up to 10 mm. across.

Plagioclase feldspar laths observed in thin section reach 2 mm. and are subhedral. The maximum symmetrical extinction of 37° measured indicates a composition of Ab_{34} (i.e., basic labradorite). Hornblende occurs as anhedral crystals 1 mm. in size. It is pleochroic from pale green-bluish green-olive green. Small crystals of hornblende enclosed within larger crystals having a different optical orientation, are common, No evidence of relict pyroxene or of hornblende pseudomorphs after pyroxene were observed. Minor amphibole veins cut across the rocks (31886).

About 1 mile east of Remine a small outcrop of a gabbro-like rock (specimen 31886A) occurs within the dunite mass, near its eastern margin. The chief component minerals are actinolitic hornblende and irregular, cloudy sericite aggregates, but minor amounts of relict augite and plagioclase are also evident. The plagioclase shows relict lath-like form and relict multiple and simple twinning. The pyroxene has simple twinning. Evidence of ophitic relationship between the pyroxene and feldspar is also preserved. Irregular aggregates of semi-opaque material, frequently with very straight edges probably represent the complete alteration of an iron-rich olivine. Other minor alteration products are talc and chlorite. Hence this rock is an altered gabbro, probably initially an olivine gabbro and is the first recorded occurrence of gabbro actually present in contact with the serpentinised dunite in the Trial Harbour area.

Devonian Igneous Rocks

The representative Devonian igneous rocks of the area are the various granite types comprising the Heemskirk Granite Complex. This stock-like complex occupies an area of about 35 square miles extending up to 6 miles inland from Granville Harbour in the north to Trial Harbour in the south. The overall shape is semi-circular with the western margin cut off by the sea. The regional trends in the country rocks surrounding the granite are approximately parallel to the granite margins, but the igneous rock cuts across the bedding of the sediments directly in contact with it, so that on a regional scale the granite is roughly concordant but on a small scale it is markedly discordant. The contact itself is vertical (plate I, fig. 4) or else dips steeply towards the country rocks.

Only the south-western corner of the complex has been mapped, but in this small area several different granite types are distinguishable and these have been mapped separately (figs. 1 and 2). The granite complex has been divided into the following types depending on the texture, composition, colour and form (the two major types are the pink granite and white tourmaline granite)—(*a*) grey granite, (*b*) pink granite, (*c*) white tourmaline granite, (*d*) porphyritic aplite, (*e*) grey micro-granite, (*f*) tourmaline nodular aplite, (*g*)

aplite, (*h*) pegmatite, (*i*) tourmaline veins, (*j*) quartz-tourmaline dykes, (*k*) pyroxene dyke and veins.

(*a*) *Grey Granite* (Specs. 31896, 31897, 31898, 31899)

The best outcrops of this rock occur at the granite hornfels contact on the shoreline three-quarters of a mile north of Remine. Wherever an actual igneous/sedimentary boundary has been observed, the granite at the contact is this grey type. Pink granite has never been seen directly in contact with the country rock. The maximum width attained by the grey granite is about 100' on the coast. Isolated patches of this granite within the pink granite have been mapped along the shoreline and a grey granite zone up to 30' wide occurs between the porphyritic aplite and the pink granite and between the pyroxene dyke (see p. 12) and the pink granite. Thus the grey granite is a marginal phase of the pink granite, appearing in the contact zones of the pink granite with both the country rocks and other granite types. In the road cutting about a quarter of a mile from Remine grey granite containing disseminated molybdenite crops out in contact with quartzites.

The rock is coarse-grained and the chief component minerals are quartz and orthoclase in crystals up to 1 cm. in size. Subordinate plagioclase and biotite are also present. Tourmaline is very rare. Biotite sometimes occurs in concentrations of up to 20% of the rock so that minor variations of the grey granite grade into biotite granite, but in the immediate contact zone (spec. 31900) there is a biotite free area 1-2 cm. wide. There is no distinct chilling of the granite at the contact but a slight general decrease in grainsize from 10 down to 4 mm. occurs.

Microscopically the contact is very irregular, with many tongues of granitic quartz-rich material extending into the country rock (specimen 31899). The most characteristic feature of the thin section of this specimen is the presence of parallel bands of magnetite grains ending abruptly against the granite, indicating that the latter is discordant to relict lithological banding in the country rock (plate I, fig. 5).

The average size of the crystals in the granite is about 1.6 mm. Graphic and myrmekitic intergrowth between quartz and feldspar is present. Both minerals are usually anhedral but some subhedral crystals do occur. Minor small quartz crystals are commonly poikilitically enclosed in larger orthoclase and plagioclase crystals, which are slightly cloudy. The maximum symmetrical extinction of multiple twinning in plagioclase is 16° and the refractive index is greater than balsam so that the composition is Ab_{68} or acid andesine. Biotite in the granite has two forms—

(*a*) Red brown to pale brown pleochroic flakes (0.2 mm.) occurring poikilitically enclosed in quartz and feldspar crystals in the granite in the immediate vicinity of the contact. This biotite is unaltered and is similar to the biotite in the hornfels.

(*b*) Dark brown to pale brown pleochroic subhedral flakes (0.8 mm.) occurring as crystals interlocking with quartz and feldspar. It is commonly partly altered to chlorite and contains minute zircon inclusions with pleochroic haloes.

Acessory zircon crystals with rhombic section in the granite reach 0.2 mm. in size.

The hornfels is composed of a granoblastic mosaic of xenoblastic quartz, feldspar and red-brown biotite crystals 0.1 mm. in size. Minor magnetite and appatite are also evident. The refractive index of the feldspar is greater than balsam and the maximum symmetrical extinction angle of 17° indicates a composition of Ab_{65}.

Other specimens of grey granite (31896, 31897, 31898) characteristically contain sagentic quartz The clusters of irregularly oriented needles responsible for this texture tend to be concentrated near chloritised biotite and sometimes near the margins

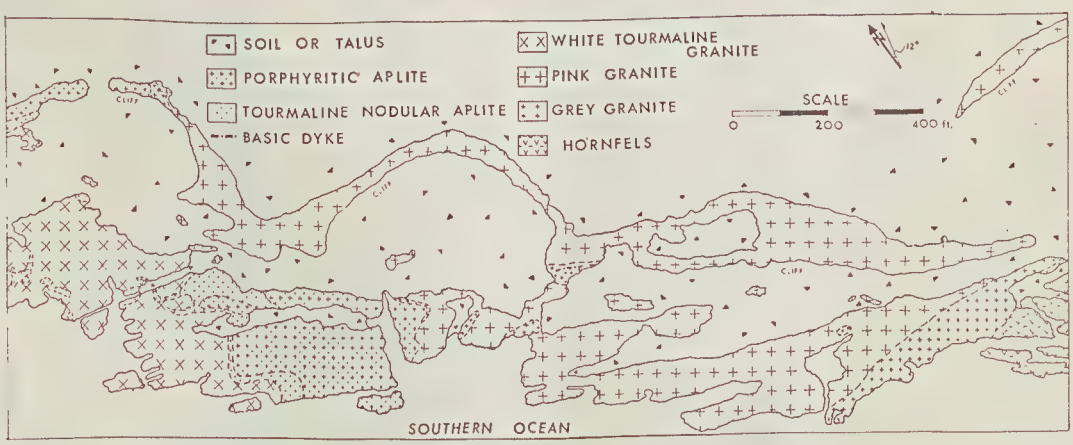


FIG. 2.—Geological Sketch Map of Coastline and Cliff Outcrop 1 mile North-North-West of Trial Harbour, showing Interrelationships of the Granite Types.

of the host quartz crystals. The needles are yellow or dark brown and are probably rutile (or in some cases tourmaline). They sometimes occur in feldspar, tending to be oriented parallel to cleavage directions. The orthoclase is anhedral and usually strongly perthitic, while plagioclase is subhedral-euhedral. The plagioclase is oligoclase in these specimens, contrasting with the andesine in the contact zone. Some of the crystals are zoned and show more strongly sericitized cores surrounded by unaltered rims. Biotite present is pleochroic from dark brown to pale brown. Accessory minerals observed include zircon (often in biotite), apatite, magnetite and sphene.

(*b*) *Pink Granite* (Specs. 31901, 31902, 31903, 31904, 31905)

This rock crops out over the southern part of the granite complex and according to Waterhouse (1916) is the main rock type comprising the Heemskirk Range. It is pink and coarse-grained consisting chiefly of quartz and orthoclase with less important plagioclase and biotite. Black tourmaline is occasionally present.

Biotite occurs in some places concentrated in layers about 1-2 cm. thick and extending up to 100′ with a fairly uniform dip and strike, though sometimes an undulatory effect is supermiposed on the general trend (see plate I, fig. 6). These biotite bands have been observed only within a short distance (440 yds.) of the contact with the porphyritic aplite or the white tourmaline granite.

The best development of the bands occurs within 100 yards of the pink granite margin. The banding present in the porphyritic aplite (see p. 11) is distinct from this biotite banding.

Textural variations range from the normal, granular varieties with a crystal size of 0.5-1.5 cm. (specs. 31901, 31902, 31903) to porphyritic types (specs. 31904, 31905) in which phenocrysts of pink orthoclase up to 1.5 cm. in size occur in an aplitic groundmass with a grainsize of about 0.5 mm. A conspicuous feature of the pink feldspars both in the porphyritic and normal pink granites is a rim of white feldspar commonly surrounding the main part of the crystal. A thin section of specimen 31904 shows that where the orthoclase phenocrysts come into contact with plagioclase a myrmekitic intergrowth between the two develops. The white rims of the orthoclase crystals may thus represent a myrmekitic intergrowth, with white plagioclase developing at the expense of the orthoclase. In specimen 31905 a large lath-like crystal with the form of a subhedral pink orthoclase crystal, is actually seen in the thin section to be composed of interlocking crystals of quartz with minor interstitial orthoclase. This feature suggests that the feldspar is being replaced by quartz. Petrographically the pink granite is identical to the grey granite.

(*c*) *White Tourmaline Granite* (Specs. 31906, 31907, 31908, 31909)

This granite occurs to the north of the pink granite, beginning about one mile north-west of Trial Harbour and extending up the coast to Granville Harbour. It varies from yellow to white and as the name implies tourmaline is an essential accessory mineral (in contrast to the rare tourmaline in the pink and grey granites). This granite type is the host rock for most of the tourmaline and tin bearing bodies in the granite complex (tourmaline nodular intrusions, tourmaline segregations, tourmaline veins, and quartz-tourmaline dykes).

It has a granular texture and the grainsize varies from coarse (spec. 31907) to medium (spec. 31906) but in general it is finer grained than the pink granite since the normal grainsize of the pink granite is 5-15 mm. compared with 1-5 mm. for this granite.

The main component minerals are quartz and orthoclase with minor plagioclase and tourmaline. The tourmaline occurs as disseminated crystals or nodules or as irregular segregations up to two feet in size, in which long tourmaline columns project from the walls into the apparent cavity that the walls surround. Black tourmaline is most common but green, blue and brown varieties have also been observed. Minor accessory minerals also present include biotite, muscovite and fluorite. The two micas occur disseminated throughout the slides examined but the muscovite (and more rarely fluorite) is typically associated with the margins of tourmaline veins and quartz tourmaline dykes since the host granite is usually greisenised by the late intrusions.

In thin section the tourmaline appears interstitial to quartz and feldspar. Frequently the quartz exhibits straight margins against the tourmaline. The pleochroism of the tourmaline is from O = indigo blue to E = pale blue suggesting that it is an iron-bearing tourmaline, schorlite.

(*d*) *Porphyritic Aplite* (Specs. 31910, 31911, 31912, 31913, 31914)

This aplite forms a minor rock type in the granite mass. The best exposure occurs on the shoreline near a mutton bird rookery one mile north-west of Remine. Small outcrops also occur in the Federation Mine area and on the coastal plain, but the exposure is not good enough to map these bodies. The texture and grainsize within the mass is extremely variable ranging from coarse (5-10 mm.) or normal phases of the grey micro-granite (type (*e*) to the normal porphyritic aplite phase in which quartz phenocrysts up to 4 mm. in size occur studded in a medium grain (0.5 mm.) aplitic groundmass.

Macroscopic pegmatitic segregations in the aplite are common and are composed of tourmaline, quartz, feldspar (orthoclase) or biotite. Tourmaline veining is pronounced and greisen zones are associated with these veins (see plate II, fig. 1). Biotite nodules (specs. 31915, 17404) up to six inches across are present, and smaller nodules of a red garnet (spec. 18873), dominantly almandine Al_{90} or Al_{60} Sp_{40}), have been identified. Disseminated grains of molybdenite and pyrite also occur in the porphyritic aplite. Tourmaline nodules have developed, but not to the extent observed in the tourmaline nodular aplite.

The porphyritic aplite is light grey when fresh but weathers to a yellow colour. It consists chiefly of quartz and orthoclase with minor amounts of plagioclase, muscovite, tourmaline and biotite.

Thin sections of specimens 31910, 31911, 31912 show contacts between porphyritic aplite and grey

micro-granite, and for completeness the petrographic descriptions of both granite types will be given in this section. The contact between the two types is sharp, but very irregular. The essential components of both are quartz, orthoclase, plagioclase and accessory chloritised biotite, muscovite and tourmaline, but the quartz content seems to be higher at the expense of the feldspar, in the porphyritic aplite than in the grey micro-granite.

Porphyritic aplite

Quartz occurs in two forms: as anhedral-subhedral phenocrysts and as anhedral grains only about 0.4 mm. in size commonly enclosed in, or forming myrmekitic intergrowth with, orthoclase. Separated crystals of quartz are frequently in optical continuity. These anhedral quartz grains do not contain minute inclusions, but streams of these inclusions occur in the anhedral-subhedral quartz. The "small crystal" type possibly represents quartz replacing orthoclase. Orthoclase is markedly dusty and the crystals are usually anhedral, though some subhedral forms are present. Plagioclase is strongly sericitized, giving a false impression of moderate relief. It occurs as euhedral-subhedral laths. It is albite. Minor chloritised biotite, shredded muscovite and rare brown tourmaline crystals are also present.

The porphyritic aplite in specimen 31912 appears to have developed from the microgranite by superposition of the aplitic texture on the granitic texture, due to the development of anhedral grains and aggregates of quartz forming a myrmekitic texture at the expense of the feldspar.

Grey Micro-granite

The quartz is clear and colourless and commonly contains streams of minute dark inclusions. The crystals range from 0.5-1.5 mm. in size and are anhedral-subhedral. Orthoclase forms interlocking anhedral-subhedral crystals with quartz; the crystal size varies from 0.5-3 mm. It is very dusty in contrast to the clear quartz and, to a lesser extent, the plagioclase. Simple twinning and perthitic texture are common.

Plagioclase occurs in subhedral-euhedral laths, 0.5 mm.-1 mm. in size, strongly altered to muscovite. It is albite as the relief appears to be less than balsam.

Ragged crystals of chloritised biotite and clear, unaltered crystals of muscovite are common accessories. This muscovite occurs in interstitial aggregates in contrast to the muscovite developed by sericitization of plagioclase.

Banded porphyritic aplite (Specimen 31914)

A characteristic banded aplite occurs at the contact zone between the white tourmaline and the porphyritic aplite (see p. 13 and plate II, fig. 4). Similar banded aplites, accentuated by weathering, are exposed nearby, within the borders of the porphyritic aplite mass (see plate II, fig. 2). The rock is pale yellow beneath a white weathered skin. It is granular with a medium grainsize (0.6 mm.). The banding is formed by grey quartz-muscovite bands ranging from 0.5 to 3 mm. thick varying in spacing.

The quartz generally forms coarse myrmekitic intergrowth with orthoclase, but in the quartz-muscovite bands an intricate semi-reticulate intergrowth between the quartz and muscovite is present. The muscovite is very ragged.

Other variations of rock types in the porphyritic aplite include a greisen (spec. 31913), consisting of quartz (phenocrysts with vacuole streams and clear groundmass crystals) and muscovite.

Biotite nodules (31915) are also characteristic. This specimen consists of a central spherical core composed of plagioclase, biotite and quartz with subordinate muscovite, accessory apatite and subrounded zircon, surrounded by a zone 5 mm. wide which is quartz-orthoclase rich and poor in biotite and plagioclase. This zone is succeeded by a grey micro-granite phase extending irregularly into the porphyritic aplite host rock. The biotite of the central core has the typical pleochroism of the biotite from the contact metamorphic zone O = red brown, E = pale brown) which suggests that the nodule may be a xenolith. The plagioclase is albite.

(e) Grey Micro-granite

This granite is a minor but distinct textural variation occurring within the porphyritic aplite mass, most commonly developed at the margins of this mass with either the grey granite or the white tourmaline granite. Apart from its occurrence, it is distinguishable from the white tourmaline granite by lack of tourmaline and higher percentage of biotite. It is distinct from the grey granite because of its aplitic texture but some variations are coarse and very similar to the grey granite. The contact between the two is however sharp and planar (see plate I, fig. 6). The detailed description has been given on this page with the porphyritic aplite because the two occur in the same specimens (31910, 31911, 31912).

(f) Tourmaline Nodular Aplite (plate II, fig. 3)

This body is mapped as a separate granite type because of the abundance of tourmaline nodules contained in it and because it occurs as discrete masses within the white tourmaline granite. The best development of the nodular aplite is attained in the boundary zone between the tourmaline granite and the porphyritic aplite.

The tourmaline nodules range from 1 cm. to 15 cm. in diameter. They usually form remarkable spherical bodies, although in some cases adjacent nodules have joined to produce a "dumb-bell" shape. Black tourmaline, quartz and minor feldspar are the most common component minerals, but occasionally blue and green tourmaline, fluorite and cassiterite occur in the nodules. Due to insufficient time, a detailed investigation of the mineral associations in the nodules could not be carried out, but it is probable that definite associations (such as blue tourmaline, fluorite and cassiterite) occur. Another investigation which could lead to profitable results relating to their origin is a study of the textural relations between quartz and tourmaline. In some nodules tourmaline columns appear to project in sheaf-like aggregates from the centre to the walls of the nodule and the space between columns is filled with quartz, while

in other nodules (e.g., spec. 32023) the tourmaline is entirely interstitial to quartz.

Microscopically the aplite, host rock (e.g., spec. 32022) to the nodules, is identical to the specimens of porphyritic aplite described previously, and the tourmaline is similar to the schorlite in the white tourmaline granite so that a detailed description is unnecessary.

(g) Aplite

Aplite dykes and veins up to ten feet wide though usually only six inches to three feet wide occur throughout the granite in the area; they are best developed in the pink granite (quartz-tourmaline dykes are more common in the white granite). At one locality an intricate network of crossing and merging aplite veins and dykes crops out.

A stereographic plot of the dips and strikes of all aplite bodies observed is discussed later.

The aplites are typically brown or pink coloured and are medium grained and granular. The usual grainsize is about 0.4 mm. The main component minerals are quartz and orthoclase, but plagioclase and biotite are also present. Chalcopyrite has been observed in one dyke. Aplitic segregations in the pink granite are often associated with the biotite banding and irregular biotite rich patches in the coarse pink granite are usually surrounded by aplitic margins.

Aplites also extend from the granite into the country rock, e.g., on the shoreline near the granite contact several irregular aplitic veins intrude the Cambrian(?) hornfelses. One dyke six feet wide and associated smaller intrusions cuts through the serpentinised dunite on the shoreline. This dyke cannot be traced back to the granite but is presumed to originate from the granitic complex (spec. 31892). This dyke contains a minor amount of weekly pleochroic pale green pyroxene, probably aegirine-augite as well as the normal quartz-feldspar component. The plagioclase has a composition of oligoclase-andesine.

Aplites within the main granite mass (31916, 32024, 32025) contain quartz with abundant vacuoles; occasionally it is sagenitic. Orthoclase and quartz form myrmekitic intergrowths. Plagioclase is euhedral and is albite-oligoclase in composition. Biotite present frequently contains zircon inclusions.

(h) Pegmatite

Pegmatite bodies are not abundant in the complex but several small dykes, segregations and pipes have been observed. The essential components are large crystals of orthoclase and quartz up to 6 cm. in size. Plagioclase crystals and columnar aggregates of black tourmaline are also usually present. A typical well developed example of a pegmatite pipe occurs on the shoreline three quarters of a mile north-west of Remine. Pegmatite veins also extend from the granite into the country rocks (spec. 31917).

(i) Tourmaline Veins

Black tourmaline veins are most common intruding the white tourmaline granite, but also occur in the pink granite and extend into the country rocks especially the Precambrian(?) slates and quartzites at Mayne's Mine). A stereographic plot of measured veins is given in fig. 3. The veins vary from 1 mm. to 20 mm. in width and are usually bounded by altered granite margins containing abundant muscovite. Quartz is a common associate and accessory cassiterite is also present. Where several of these veins are closely spaced so that the granite between them is entirely altered, the rock type produced is very difficult to distinguish from the quartz-tourmaline dykes, and these two types of bodies cannot always be mapped separately where exposure is not good away from the coastline.

Tourmaline veins (and also the quartz-tourmaline dykes) are late stage features of the granite mass, as they cut across all other bodies. Veins have been observed to cut through tourmaline nodules, sometimes causing relative displacement of the two halves of the nodule.

Ward (1909) and Waterhouse (1916) give a discussion of several quartz-tourmaline dyke and vein types related to cassiterite mineralisation. Due to lack of time the writer has not been able to extend this investigation.

(j) Quartz-Tourmaline Dykes

These bodies have been mapped and their dips and strikes plotted stereographically (see fig. 3). The dykes vary in thickness from a few inches up to 30 feet and can be traced for up to half a mile. Tin mineralisation is associated with them and most of the mines or prospects in the area are situated on these bodies. The dykes occur in both the white tourmaline and the pink granites, but are commoner in the former. They appear and disappear abruptly with no apparent change in thickness and so it is impossible to map any displacements due to faulting within the granite using these bodies. The essential component minerals of the dykes are quartz and black tourmaline (blue and green tourmaline varieties occur rarely).

(k) Basic Veins and Dykes

Within the pink granite, near the contact with the hornfels on the coast several pyroxene veins 1-5 cm. in width extend roughly parallel to each other across the granite contact and can be traced for several hundred feet in both the granite and the hornfels. These veins cut aplite veins in the granite. They are composed mainly of diopside, but minor sericite, amphibole, axinite and sphene may also occur (spec. 31919). The diopside commonly grows on prismatic crystals perpendicular to the margins of the veins, but in some sections a granoblastic pyroxene mosaic is also evident. The composition is 48% diopside, 52% hedenbergite $\pm$ 2% (optical properties: $2V = 60° \pm 1°$; $Z\ C = 39° \pm 1°$, $\alpha = 1.700 \mp .001$, $\beta = 1.708 \pm .003$, $\gamma = 1.728 \pm .001$). All pyroxene composition estimates have been obtained using determinative curves from Deer, Howie and Zussman (1962; Vol. 2, fig. 22 p. 62). The pyroxene near to the sericite aggregates is altered to actinolite (x = very pale green, y = pale green, z = pale blue-green).

The best development of a basic dyke is exposed in the granite cliff nearly one mile north-west of Remine (plate II, fig. 5). It extends up the cliff face varying in width from a few inches to six feet.

It consists of large dark green euhedral-anhedral pyroxene crystals enclosed in an aplitic groundmass, which in turn is in contact with grey granite merging into normal pink granite. On weathered surfaces the aplite surrounding the pyroxene crystals in the dyke shows peculiar intricate "worm-like" patterns, the cause of which is unknown.

Single crystals of pyroxene may reach 10 cm. in size. In thin section it is pale green (31920, 31921). The composition is 34% diopside, 66% hedenbergite ±4% (refractive indices: $\alpha = 1.709 \pm .003$, $\beta = 1.718 \pm .005$, $\gamma = 1.735 \pm .003$). Other minerals present include axinite, sometimes showing comb structure, sphene, apatite and calcite.

The aplitic groundmass to the pyroxene phenocrysts is white and medium grained (0.5-2 mm.). The chief component minerals, quartz, plagioclase, and orthoclase, occur in two distinct forms.

(*a*) Specimen 31918. In this specimen the quartz is frequently embayed and contains many streams of minute inclusions. Crystals 2 mm. in size occur. The feldspar is intensely altered and cloudy and cannot be differentiated into feldspar types. The crystals reach 2 mm. in size, varying from anhedral to subhedral. Accessory minerals in this slide are characteristic:—

Sphene occurs as small anhedral aggregates or as discrete wedge-shaped crystals and is brown.

Apatite is evident as anhedral grains (0.05 mm) with irregular fracturing.

Chlorite is pale green with anomalous blue interference colours and moderate relief. It is interstitial to the feldspar and has a shredded form. The interference figure is negative with a low axial angle.

Fibrous mineral aggregates forming a fan structure occur and are similar to chlorite but have a stronger birefringence than is normal for chlorite. Interstitial carbonate (probably calcite) is present, as well as small brown weakly pleochroic crystals of tourmaline. Finally a colourless, interstitial mineral with moderate relief and strong birefringence has been observed. Some slightly anomalous interference colours are evident. It has a biaxial positive interference figure with a moderate axial angle. It typically occurs in acute-angled sections surrounded by a low birefringent rim. It is probably prehnite pseudomorphing axinite, because axinite often occurs as acute-angled crystals, and is present in the basic dyke (spec. 31921).

(*b*) Specimen 31920. In this slide the groundmass quartz and plagioclase form a granular mosaic (grainsize 0.2 mm.). The plagioclase has a composition of Ab_{66} (andesine). It is clear and unaltered in contrast to strongly sericitized orthoclase and has a weak preferred orientation. Accessory sphene and prehnite are also present. The texture of this groundmass is quite distinct from the texture of an aplite type (*g*) but similar to the quartz-feldspar mosaic of the hornfels.

Stereographic Investigation of Aplite, Tourmaline and Quartz-Tourmaline Veins or Dykes and Biotite Bands in the Granite Complex

Biotite Banding

Twenty poles to biotite banding in the pink granite are plotted in figure 3. A marked concentration occurs, indicating that most bands strike at about 60° and dip to the south at 25°. This maximum is significantly close to the strike and dip of the planar contact between the porphyritic aplite and the pink granite (the pole of this contact is plotted on the same diagram). This substantiates the proposal that the biotite bands are marginal flow phenomena in the pink granite, possibly induced by the later intrusion of porphyritic aplite (see p. 15).

Aplite Veins or Dykes

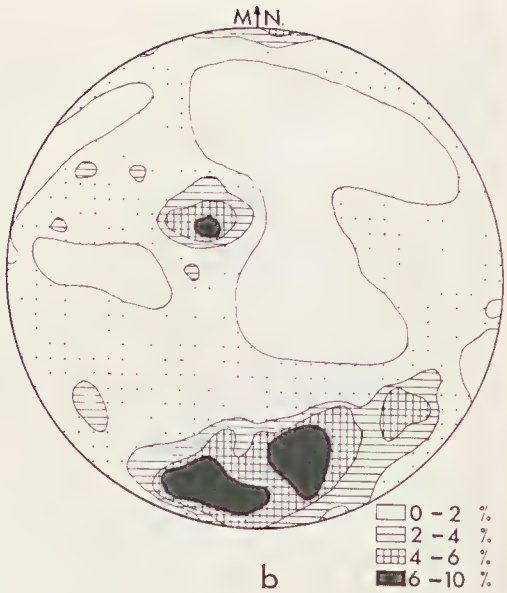
One hundred poles to aplitic bodies have been plotted in figure 3. There are three marked concentrations, representing aplite veins with a strike of 68° dip 60° N, and 98° dip 75° N, and 50° dip 25° S. The last set has a similar orientation to the biotite bands and represents aplitic veins or bands which commonly accompany the biotite banding. The other two sets are unrelated to jointing in the granite, in contrast to the later forming tourmaline veins and quartz-tourmaline dykes (see below) and so some factor other than jointing must have governed the orientation of the aplitic intrusions. It would be of interest to determine whether these sets of aplite veins are constant in orientation throughout the complex, or whether variations occur, and the pattern obtained for aplite in the south-western corner of the complex is only a local expression of an overall pattern for the whole complex.

Tourmaline Veins and Quartz-Tourmaline Dykes

Figure 3 shows that the tourmaline veins and the quartz-tourmaline dykes have similar girdle conentrations with a strike of 15° and a near vertical dip. The presence of a well developed girdle maximum is probably slightly exaggerated because in many cases the dips of the bodies could not be determined accurately, but appeared to be very steep. Comparing the concentration of these poles with figure 4 showing a stereographic plot of the poles of 500 joints in the granite, it is evident that the dykes and veins correspond with the weaker of the two girdle concentrations of joint poles. It is not known why these late intrusions should be identical in orientation with one set of joints and not the other, more prominent set.

Interrelationships of the Granite Types and the Origin of the Complex

At a point (1 mile north-west of Remine) on the shoreline near the southern boundary of the white tourmaline granite, a characteristic banded structure is exposed marking the contact between the white tourmaline granite, the tourmaline nodular aplite and the porphyritic aplite (see plate II, fig. 4). The tourmaline granite passes gradually into the tourmaline nodular aplite due to increasing abundance of nodules and decreasing grainsize, but the nodular aplite passes abruptly into a microgranite phase marking the



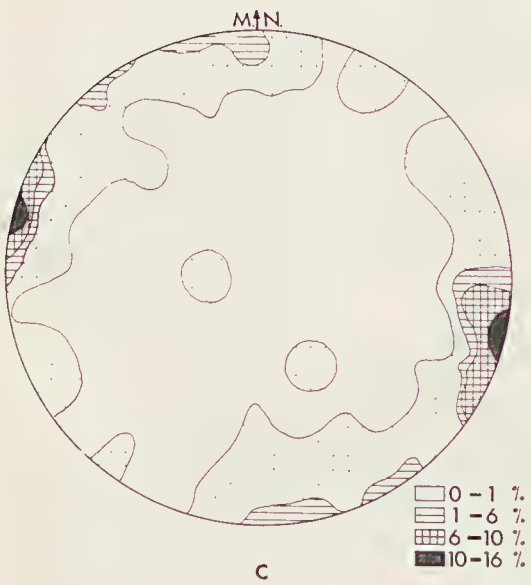


FIG. 3.—Stereographic Plots (lower hemisphere) of—
(*a*) Biotite Banding in the Granite (20 poles).
(*b*) Aplite Veins and Dykes (100 poles).
(*c*) Tourmaline Veins (100 poles).
(*d*) Quartz-tourmaline Dykes (75 poles).

base of the porphyritic aplite. The microgranite passes into a banded aplite and finally into the normal porphyritic aplite.

An actual contact between pink and white granites has not been observed because of poor outcrop. Where rock exposures are good on the shoreline an intervening porphyritic aplite occurs between the two granites. As the aplite cannot be traced away from the coastline, it is not known whether it is merely a local intrusion or if it always occurs as an intermediate rock type between the white and pink granites. The fact that the contact between the porphyritic aplite and the two granites is sharp (e.g., plate II, fig. 1) and not gradational suggests that the aplite is a late intrusion.

There is no definite evidence for chilling at any of the granite/granite contacts. Any grainsize variations that may ocur are also evident in areas away from contact zones and so cannot be considered as contact phenomena. However biotite banding in the pink granite (plate I, fig. 6) and muscovite-quartz bands in the porphyritic aplite are more pronounced in rocks near the contact between these two bodies (plate II, fig 2). The writer considers that this banding is due to flow in the granitic magma during intrusion and is more pronounced near the margins of the intruding bodies where viscous drag in moving magma would be the greatest.

The intrusion of the porphyritic aplite and the white tourmaline granite probably occurred after the intrusion of the pink granite magma, but before the latter mass had cooled, so that no chilling or discordant brecciated structures resulted. The porphyritic aplite and the white granite were separate magmas as the contact between the two is sharp. The banding developed in the aplite is roughly parallel to the contact and suggests relative movement of the two bodies producing flow banding in the still fluid aplite. Thus the writer suggests that the porphyritic aplite magma was later than both the major granite types, and intruded between the white and pink magmas while they were still hot. Volatile-rich segregations in the aplite magma formed tourmaline and quartz patches when the magma crystallized. The quartz phenocrysts possibly represent original quartz crystals suspended in the magma. The presence of almandine or almandine-spessartite nodules in the porphyritic aplite and not in other granite types suggests special conditions existing, at least locally, in the aplite magma allowing the formation of the nodules on crystallization of the magma (Chinner (1962) considers these conditions to be largely compositional). A possible alternative is that these nodules are xenolithic relict fragments of country rock and did not form by igneous crystallization. The xenolithic origin is substantiated by the possible presence of biotite-rich xenoliths in the same mass.

Although the magmas giving rise to the pink and white intrusions had the same bulk composition the later white granite magma had a high content of volatile materials. These volatiles tended to accumulate near the roof of the body, and formed the tourmaline nodular aplite when the mass cooled. This would explain the apparent gradational contact between the tourmaline nodular aplite and the white tourmaline granite described on page 11. Volatile rich segregations throughout the white tourmaline granite magma gave rise to the isolated patches rich in tourmaline nodules and the tourmaline bodies observed.

The last major phase of igneous intrusion in the Heemskirk Complex involved the tourmaline veins and the quartz tourmaline dykes. These were accompanied by greisenization and mineralization. The direction of intrusion of these bodies is related to, and was probably governed by fissuring developed in the granite (fig. 4).

A possible alternative origin for the different granite types in the complex could be argued from a metasomatic viewpoint by attributing the different types to changes taking place in the original pink granite resulting from the activity of volatile rich fluids passing through the granite. The fluids were active just prior to or simultaneously with the intrusion of the tourmaline veins and quartz-tourmaline dykes. However this theory would not explain the sharp contacts observed between the porphyritic aplite and the pink granite shown in plate II, fig. 1, nor could it explain the rarity of tourmaline segregations in pink granite compared with the common occurrence in white granite of disseminated tourmaline segregations free of surrounding alteration of the host rock. This lack of alteration points to actual magmatic crystallization of tourmaline rather than a post-crystallization metasomatic formation of the mineral.

Minor variations within the white tourmaline granite mass are however, explainable by metasomatic activity accompanying the intrusion of tourmaline veins and quartz-tourmaline dykes. The chief result is the replacement of orthoclase by quartz. This is best developed in the porphyritic aplite and the white tourmaline granite where the tourmaline veins are most common.

The grey granite is only a marginal variation of the pink granite and is not a separate intrusion. It is not known why the orthoclase changes colour but two possible explanations are:—

(i) Temperature of formation is governing factor in imparting a pink colour (lower temperature of the margin results in more rapid crystallization and the formation of grey orthoclase).

(ii) Bleaching of the feldspars of the pink granite caused by loss, to the rocks adjoining the margins, of the component imparting the pink colour to the orthoclase.

The clearcut intrusive igneous contact with the country rocks (plate II, fig. 4) indicates that the Heemskirk Complex was a magmatic intrusion, but no marked chilling of the granite margins is evident. Two characteristic features of the country rocks immediately surrounding the granite are the general parallelism of regional trends to the margins of the complex and the fairly consistent dip away from the granite mass. These features provide a possible explanation to the room problem involved in the emplacement of the intrusive

magma, since they may reflect a diapiric intrusion of the granite causing an upward bowing of the country rocks and giving rise to the two features described.

An interesting, though very tentative, comparison can be made between the Heemskirk Complex and the Caribou Mountain Pluton, California (Davis 1963). Davis proposed that this pluton was emplaced in the centre of an antiform but that this antiform had developed prior to the granite intrusion. The pluton has a domical form and dominantly concordant contacts; these criteria are consistent with a mesozonal emplacement (Buddington 1959). Davis records no chilling of the granite at the contact.

Age of the Complex and Relation with other Tasmanian Granites

The Heemskirk Complex is similar petrologically and compositionally to other acid bodies occurring on the west coast, the north-eastern and eastern parts of Tasmania; many of these masses are multiple intrusions. The most abundant rock type in these bodies is a coarse grey granodiorite or adamellite (Spry 1962b). The pink granite of the Heemskirk Complex is not a common type, but is similar to the red Coles Bay Granite which is associated with the normal grey granodiorite. No petrographic evidence was observed suggesting that the granites of the Heemskirk Complex could be metasomatized granodiorites, with microcline replacing plagioclase similar to the granites from Coles Bay and the Pieman Heads (Walker 1957, Spry and Ford 1957). However some of the orthoclase crystals which were termed coarsely perthitic in the petrographic descriptions are similar to structures described by Boone (1962, fig. 10). Boone proposed that these orthoclase-plagioclase composite crystals, generally with plagioclase minor in quantity, represented replacement of plagioclase by orthoclase, but the replacement mechanism forming the same textures in the Heemskirk granite is considered unlikely because:—

(i) closely spaced plagioclase crystals enclosed in a single orthoclase crystals are not in optical continuity;
(ii) large euhedral plagioclase laths occur, but orthoclase crystals are anhedral, rarely subhedral and are not lath-like;
(iii) no intermediate stages of replacement between sericitized but only slightly cloudy large euhedral plagioclase crystals, and extremely cloudy, anhedral orthoclase crystals containing small anhedral plagioclase crystals, have been observed.

Solomon (1962) states that the Tasmanian granitic stocks were intruded following the development of the Tabberabberan structures. The intrusions can be limited stratigraphically to post-Silurian and pre-Permian since Silurian sediments are metamorphosed (p. 5) and Permian sediments rest unconformably on granite in North-East Tasmania (Blissett 1959).

From K:Ar isotope ratio work the Heemskirk Granite has been dated at 338 million years (i.e., Lower Carboniferous) (Evernden and Richards 1961) but C. Brooks (1963 pers. comm.) in later K:Ar work has obtained a date of 351 million years. Davis (1962) obtained a minimum age of 375 million years and a probable age of 391 million years (Middle Devonian) for the Coles Bay granite.

STRUCTURAL GEOLOGY

The general trends of the country rocks in the Trial Harbour district are 90°-120° approximately parallel to the granite intrusion. Carey (1953) proposed that the Heemskirk Granite occurs in an anticlinal zone, extending north-east through the Meredith and Hampshire Hills Granites. No conclusive evidence for this structure was observed in the small area examined, although possible minor drag folds in the Silurian Amber Slate suggest that the steeply dipping strata are the south-western limb of an anticlinal structure to the north-east.

Folding

The thinly bedded slates of the Oonah Quartzite and Slate frequently show minor intricate fold structures which are probably related to deformation accompanying the granite intrusion. Outcrop is too poor to enable determination of any definite orientation of these folds.

The Cambrian(?) rocks are generally massive, but where thinly bedded strata occur they have near vertical dip and rarely show minor folding.

The thinly bedded Amber Slate strikes consistently at 110°-120° along the coastline and generally dips steeply to the north-east for the northern half-mile of outcrop, but then swings over and dips steeply to the southwest for the remaining exposures to the south. At the northernmost outcrop and in one locality one and a half miles south of Remine minor folding is prominent and varies from isoclinal to recumbent (see plate II, fig. 6). Minor thickening in the cores occurs and it is probably a combined concentric-similar type of folding. Very small amplitude (two inch) kink folds are present on the limbs of the minor folds (these vary up to 5 feet in amplitude and up to 20 feet across). The folds generally plunge at about 20°-30° in a direction 90°-110°, and if they represent minor drag folds on the limbs of a major fold then this major fold is an anticline to the north-east.

Faulting

The major fault in the district is the fault bringing Cambrian(?) volcanics into contact with Silurian strata. This trends at 110°, and the north-east side is upthrown. It is probably an extension of the Firewood Siding Fault (Blissett 1962). Because of the steep dips of the strata and the lack of knowledge of the thicknesses of Ordovician and Cambrian (?) rocks in the area it is impossible to estimate the movement on the fault. This fault must cut the coastline between a small outcrop of Cambrian(?) volcanics and the Amber Slate but it is not exposed. The rocks which crop out about 50 yards to the south of the volcanics are massive and could not definitely be identified as Silurian as they differ from the normally thinly bedded Amber Slate. If the massive rocks are Cambrian(?) then an extremely complex structure involving both faulting and folding would be needed to explain the relationships of the rocks exposed.

Other faults have also been mapped in the country rocks but they are only minor, with displacements of only a few feet.

Nature of the Contact between the Precambrian (?) and Cambrian (?) Rocks

There is an unsettled controversy concerning the relation between the younger Precambrian sediments (such as the Oonah Formation) and the Cambrian rocks (Crimson Creek Group and Dundas Group), on the West Coast of Tasmania. It has variously been reported that Crimson Creek Group rocks overly the Oonah Quartzite and Slate either conformably (Spry 1962a) or unconformably (Blissett 1962). At Trial Harbour the Oonah Formation and the Cambrian(?) rocks are conformable but at the mouth of Montagu Creek an irregular contact between the two occurs and strata of both formations end abruptly against this contact. The rocks are too altered and the contact is not well enough exposed to determine whether it represents a fault contact or an unconformable or disconformable contact. Specimens 31924 (Precambrian), 31978 (Cambrian) were collected from either side of the contact. The Precambrian quartzites are strongly quartz-veined, but these veins are rare in the Cambrian siltstones.

Jointing

Granite

Five hundred joints in the granite have been measured and the poles plotted in fig. 4. This figure shows a well defined girdle with two maxima at right angles representing joints striking 10° and 100°. The 10° set is the dominant one. The origin of these joints is unknown. The two sets are probably related and since the tourmaline veins and dykes follow the 10° set the joints probably formed soon after the intrusion of the main part of the complex, but before or at the same time as the last phase of activity involving the intrusion of the tourmaline veins and the quartz-tourmaline dykes.

Hornfels

Only 60 poles of joints in the Cambrian hornfels were plotted (fig. 4), but these show 3 maxima representing 3 main sets of joints (2 are close and may not be separate sets). One set strikes 100° and is near vertical so that it is similar to the major joint set in the granite, but the other set (or sets) strikes 84° and dips at 60° N so that it is distinct from the granite joints. The jointing in the hornfels is probably related to the granite intrusion but insufficient poles have been plotted to allow reliable interpretation.

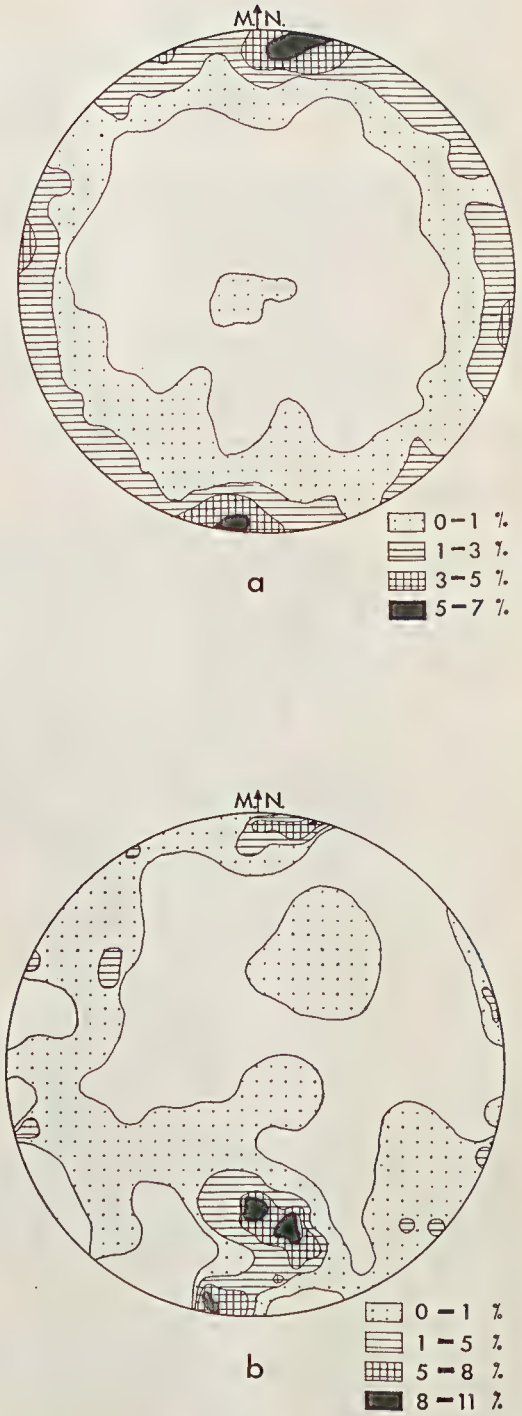


FIG. 4.—Stereographic Plots (lower hemisphere) of—
(*a*) Jointing in the Granite (500 poles).
(*b*) Jointing in the Cambrian(?) hornfels (60 poles).

ECONOMIC GEOLOGY

History of the Mining Field

Early exploration of the Heemskirk mineral field took place from Waratah. The first party was led by C. P. Sprent and found traces of tin near Mt. Heemskirk in 1876. Following recommendations by Sprent, mining syndicates began sluicing for alluvial tin in the district, but by 1897 vein tin, or tin disseminated in granite host rock was being obtained in small quantities from the Montagu, Cumberland, Empress Victoria, Cornwall and Cliff mines in the area. Early speculation based on the belief that the Heemskirk field would become a "second Mt.

Bischoff", resulted in the erection of batteries, driving of adits and sinking of shafts into outcrops which had not been sufficiently well prospected. This latter fact added to the confusing effect of the abundant black tourmaline (frequently mistaken for cassiterite) culminated in the collapse of most of the mining ventures, and gave the field a bad name.

Subsequent mining operations have centred around the Federation area and at Mayne's Mine (where a very rich pocket of tin was discovered). Waterhouse (1916) thoroughly described all the mines and prospects of the area. Since many of these were still in operation or were still accessible at the time of Waterhouse's investigation, his observations were far more complete than any the writer could make. For this reason the description of the economic geology of the area is limited.

Since 1916 adits have been driven in the Black Face area and at Coleman's workings, but these have not resulted in any significant discoveries of tin.

Mineralisation

(a) Associated with the Serpintinised Dunite

On a ridge a quarter of a mile east-south-east of Remine, three adits and a shaft have been driven into a nickel-bearing dunite. The writer has identified heazlewoodite (see p. 7) and zaratite from the workings (specimens 10532(i), 10532(ii)).

Waterhouse (1916) described the nickel workings fully and Williams (1958) gives a detailed account of the mineralogy. Williams proposed that the nickel accompanied the original intrusion and segregated before serpentinisation. He records the presence of chromite and sphalerite as well as the nickel bearing minerals pentlandite (most abundant), heazlewoodite, shandite ($Ni_3Pb_2S_2$) and millerite (a breakdown product of heazlewoodite). Blissett (1962) records assays of 18.6% and 14.6% nickel from samples from the dumps.

Local segregations and veins of magnetite also occur in the dunite but these are not extensive enough to be economically important.

(b) Associated with the Granite

The mineralisation associated with the granite is the only mineralisation of economic significance in the area. The tin is invariably connected with late tourmaline rich intrusions in the granite, and most of the old workings occur in the white tourmaline granite, where it is cut by quartz-tourmaline dykes or tourmaline veins. A few mines are present in the pink granite and are also associated with quartz-tourmaline intrusions, e.g., Empress, Victoria, Sweeney's and Wakefield and in one case (Mayne's Mine) tin mineralisation occurs in the Oonah Quartzite and Slate country rocks, accompanied by extensive tourmaline veining.

Federation Workings

Most of the mining operations in the area have been carried out in the Federation Mine Creek, extending from the Western Workings (Geason's, Tributer's, Fowler and Dunn's) through the Central Workings (Black Face, Munro's, Long Tunnel) to the minor Eastern Workings. In between these mines there are many prospect trenches and pits in quartz-tourmaline bodies containing minor cassiterite and pyrite. In one such prospect 200 yards south of the Black Face, cassiterite is associated with well developed cubic pyrite crystals (specimen 12565). In spite of the extent of the Federation Workings, especially in the Black Face area, comparatively little tin has been obtained (less than 800 tons of cassiterite (Blissett 1962)). Large scale mining operations finally ceased in 1938.

In the Federation area tourmaline nodular aplite, tourmaline veins, and quartz-tourmaline dykes occur in a white tourmaline granite host rock. Crustification texture in quartz may develop along the margins of the tourmaline veins (e.g., specimen 18650). Black tourmaline is the most common tourmaline variety, but green and blue tourmaline are also evident (specimens 18649, 18650, 18651). The cassiterite is usually associated with the latter two varieties. Muscovite and fluorite are also present. The cassiterite either occurs as disseminated grains in the granite host, in veins or in rich segregations and varies from a black to dark-brown colour. Other minerals recorded include bismuthinite and wolframite (Waterhouse 1916).

Coleman's Workings

These workings are the only ones at present producing tin in the district. E. Coleman has mined tin on this lease since 1943. It is situated on a 1400' spur marking the source of Montagu Creek and is about 500 yards south of the Central Workings of the Federation Mine. White tourmaline granite containing some tourmaline nodules is cut by many tourmaline veins and quartz-tourmaline dykes and the tin mined has been obtained from rich segregations, tourmaline nodules and disseminated grains, similar to the occurrence in the Federation Workings. Brown and black cassiterite are present, and minute crystals of native copper or cuprite are occasionally evident (specimens 12566-70, 10023). This deposit is low grade (probably it would bulk about 1% cassiterite) and its possible development is hampered by its location on top of a steep ridge.

Another mine of interest is Sweeney's Mine, which is about half a mile south of Cumberland Lake. The lode occurs in quartz-tourmaline dykes in pink granite and contains sphalerite, cassiterite and stibnite in a gangue of pyrite, siderite, quartz and fluorite (specimens 10491, 13517).

The best cassiterite obtained by the writer came from a dump at a prospect about a quarter of a mile north of the Cliff Mine. This specimen (12572) contains cassiterite crystals up to 0.5 cm in size occurring in a greisen groundmass consisting of muscovite, fluorite, quartz and green tourmaline. The shaft from which the specimens originated is now flooded.

The remaining mines in the district (Prince George, Cornwall, Cliff, Empress Victoria, Montagu, Wakefield and Mayne's) contained cassiterite associated with tourmaline and quartz, and occasionally pyrite and arsenopyrite.

A similar association of tin with tourmaline has been recorded from granites in south-west England (Dewey 1948) and in Malaya (Hutchinson and Leow 1963). Tourmaline nodules and late cutting quartz-tourmaline dykes have also been recorded in the Malayan granites.

GEOLOGICAL HISTORY

The geological record in the Trial Harbour area began with the deposition of sands and silts in late Precambrian(?) times, with possible volcanic activity towards the end of sedimentation. Folding, uplift and erosion may have occurred before subsequent sedimentation and volcanic activity resulted in deposition of siltstones, tuffaceous siltstones, tuffs and breccia, accompanied by intermittent basic lava flows on the ocean floor. However conformable deposition of Cambrian(?) rocks on Precambrian(?) cannot be ruled out, because of uncertainty of the contact relationship. Emplacement of serpentinised dunite also probably took place in the Cambrian Period.

There is no record of the Ordovician Period in the area, and the next rock type to form was the Silurian Crotty Quartzite, followed concordantly by siltstones, calcareous siltstones and an occasional cross bedded quartzite, all comprising the Amber Slate. These two formations were probably deposited in shallow water.

Folding possibly took place before the next phase of activity, when in Devonian(?) times, a major plutonic igneous complex was intruded, beginning with a pink granite, followed closely by a white tourmaline granite, and finally by minor intrusions of porphyritic aplite, aplite, pegmatite, quartz-tourmaline dykes and tourmaline veins, accompanied by cassiterite mineralisation and local greisenisation of the granite.

No record is preserved of the Carboniferous-Permian Periods. The final events recorded are probably sub-aerial erosion giving rise to prominent topographic levels (e.g., lower coastal surface). Minor Quaternary changes in sea level are also evident.

ACKNOWLEDGEMENTS

This work was carried out as part of an Honours course and the writer in indebted to the staff and students of the Geology Department, University of Tasmania for helpful discussion and suggestions during the year. Special thanks are due to Dr. A. H. Spry who supervised the work. The writer also wishes to gratefully acknowledge the help of Mr. W. Brook, who carried out a plane table and geological survey of the coastline outcrop in 1960 and kindly allowed use of his map for a detailed coastline study. The outcrop outline of fig. 2 is taken from this map. Thanks are also due to Mr. and Mrs. T. McGee who generously allowed use of their cottage at Trial Harbour during field work.

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PLATE I.

FIG. 1.—Scour of coarse siltstone in fine siltstone.

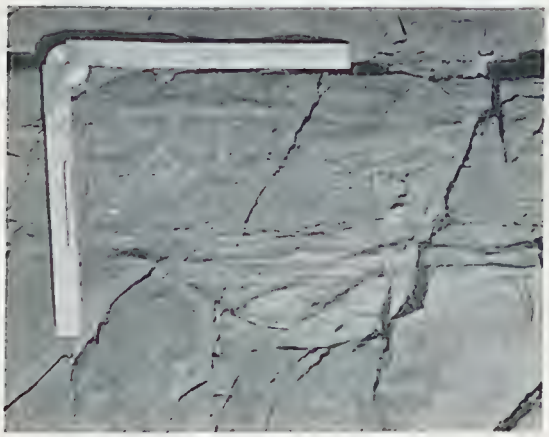
FIG. 2.—Current bedding in quartzite of the Amber Slate.

FIG. 3.—Minor basic intrusion; plagioclase laths set in granoblastic mosaic of hypersthene and biotite (Ord. light; scale mark = 0.5 mms).

FIG. 4.—Granite (right)/country rock (left) contact on the shoreline outcrop. Outcrop about 20′ high.

FIG. 5.—Photomicrograph of granite/country rock contact. Banding in the country rock (right) ends abruptly against the granite (left). (Ord. light; scale mark = 0.5 mms).

FIG. 6.—Biotite banding and quartz veining in pink granite. The contact between the grey granite (marginal phase of the pink granite) and the grey microgranite (marginal phase of the porphyritic aplite) occurs near the base of the photograph.



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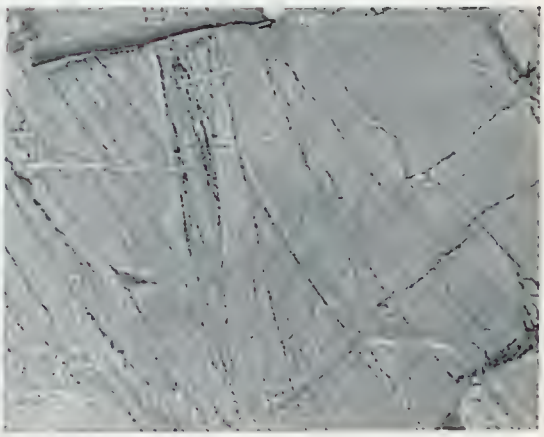

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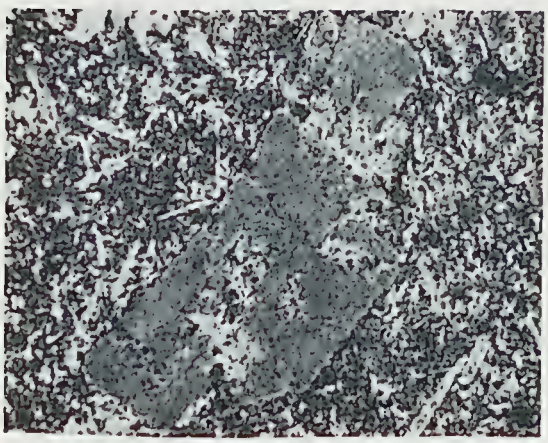

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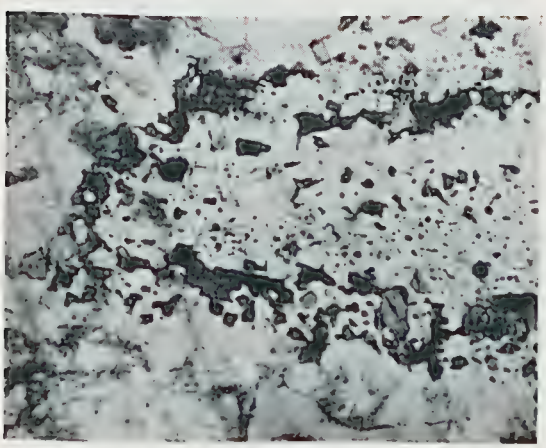

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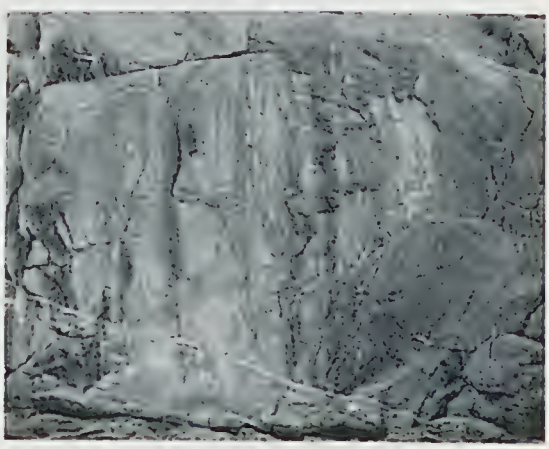

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Plate II.

Fig. 1.—Prominent tourmaline veining with greisen margins mid-right) and planar contact between biotite banded pink granite and porphyritic aplite.

Fig. 2.—Banded porphyritic aplite.

Fig. 3.—Tourmaline nodular aplite and quartz-tourmaline segregation.

Fig. 4.—Contact between white tourmaline granite (below) grading into tourmaline nodular aplite and porphyritic aplite (top). Note banding in porphyritic aplite parallel to the contact.

Fig. 5.—Pyroxene dyke intruding pink granite.

Fig. 6.—Folding in Silurian Amber Slate. Scale 10′ from base to top.

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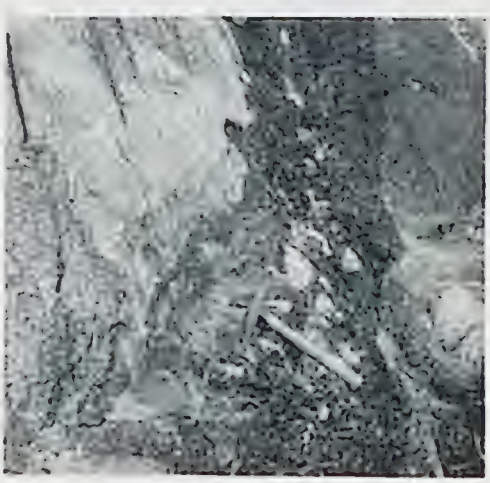

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TASMANIAN MUSEUM AND ART GALLERY: HISTORICAL NOTE

By

W. Bryden

It is appropriate in this year 1966 when Volume One Hundred of the Papers and Proceedings of the Royal Society of Tasmania is to be published that there should be some review of the development and growth of the State Museum in Tasmania.

It should not be thought that though this island State was founded in 1803 when Lt. Bowen, with the ships "Ocean" and "Lady Nelson", formed a settlement at Risdon near Hobart, no Museum was opened until a much later date. Far is such a thought from the truth, for there is good reason to believe that as early as 1828, collections were being made with the thought in mind that when a Museum was actually opened, the collections would rest there. In truth we should say that a Museum was founded as early as 1828, for then the beginnings of collections of various kinds of animal and plant life had been started, catalogued and preserved.

Several Societies were formed in Van Diemen's Land in the early 1800's and by the early 1840's many scientific papers had been read and discussed, most of them dealing with the local fauna and flora. By 1830 deliberate and painstaking efforts were made to collect minerals and rocks, animals and plants, all of which were gathered together by enthusiastic amateurs who had the love of learning in their bones, it being understood that these items would form the beginning of Museum collections.

In this connexion the following Societies should be mentioned:—

(*a*) The Van Diemen's Land Agricultural Society was formed in 1821 but there is little record of museum collections and no record of the formation of a museum.

(*b*) The Mechanics' Institution of Hobart was founded in 1826 under the patronage of Governor Arthur. Piesse states ". . . In 1838 Sir John Franklin obtained a grant of £100 a year from public funds. In reply to a deputation from the Institution he said that 'in the new Customs House* now in progress, there was a room constructed which was intended for a Museum . . .'".

(*c*) In 1829 the Van Diemen's Land Scientific Society was formed and among the objects was the formation of a Museum.

It was stated in the original announcement ". . . and its chief objects are intended to be the collection of useful information regarding the island and its productions, so as to promote the prosperity of the colony—a Museum of natural history for the formation of which Van Diemen's Land is so singularly adapted, abounding as it does with new and unknown specimens in all the three kingdoms of nature . . .".

On Saturday, 16th January, 1830 (according to the "Hobart Town Courier" of 23rd January of that year) the Annual Meeting was held and in the presence of the Patron (His Excellency Colonel Arthur), the President (Dr. John Henderson) delivered his inaugural address.

Piesse, in "The foundation and early work of the [Royal] Society [of Tasmania]" states "thus successfully launched, the Society met monthly . . . and it established a Museum,".

(*d*) Piesse states "Early in 1842 Lady Franklin purchased two blocks of land, one of 400 acres, and one of 10 acres, together forming the 'Ancanthe' estate, situated in Kangaroo Valley†, a secluded but picturesque valley at the foot of Mt. Wellington, three miles from the city and a mile from New Town. On the smaller block Sir John Franklin, on 12th March, 1842, laid the foundation stone of a Museum . . .".

"The [Museum] Trust, in regard to the Tasmanian Society, directed that until a College or University, having the approbation of the Bishop, should be established, the trustees were to permit the Museum to be used and inspected by the Society, for sometime established in Hobart Town called the Tasmanian Society or by any other Society or Societies, person or persons, or by the public at large as the trustees might think proper."

"Of the collections little record remains: they are said to have come into the custody of the Society, no doubt at about the time when the cases and fittings were purchased by the Society . . ."

[Note.—In 1853 the Royal Society of Tasmania purchased the cases and fittings of the Ancanthe Museum and re-erected them in the Museum then situated in Harrington Street, Hobart.]

It was when Sir Eardley Eardley-Wilmot was Lt.-Governor that a concerted effort was made by all concerned to bring about a reconciliation between the various scientific societies in Van Diemen's Land. On 14th October, 1843, this was achieved to some considerable extent. Unfortunately Wilmot lived to see little of it, but it is no less interesting to note that just prior to his proposed departure from the State, he fell ill, was put to bed in the cottage then used as an official residence by the Secretary to the Governor, where he died. That cottage later became part of the Tasmanian Museum and in fact it is still used as a definite part of the Museum organisation.

It is interesting to trace the development of this Museum through the years until it was a firmly established institution.

* Customs House—Since enlarged and renovated to become the State Houses of Parliament.

† Later named Lenah Valley.

The Royal Society of Tasmania, after its formation in 1843, was zealous in its efforts to develop a really fine Museum, one worthy of the State and of the collections, and of those who displayed such interest in scientific matters. Throughout the years of the nineteenth century the Society played a very prominent part in the development of the State—it pioneered new ventures, developed a wide horizon and gave advice and criticism freely and willingly, advice often asked for by people of the day, criticism often wise enough to make others halt in their actions until further consideration had been given to new proposals.

In the following pages, extracts have been taken from Annual Reports and from the Minute Books of the Royal Society of Tasmania, which concerned the Museum and its development. It is indeed a great memorial to the efforts of all concerned that such a Museum and Art Gallery was fostered and developed and that such collections were made.

1846 Report.—" agreeable to the suggestions of His Excellency (Sir William Denison), the President of the Society, the Council intend, as soon as they have adequate funds at their disposal, to fit up the rooms of the cottage* lately occupied by the Secretary, as a Museum and Reading Room ".

" His Excellency has, also, with the most laudable liberality and zeal for the welfare of the Society, engaged to present a valuable collection of specimens of Natural History to the Museum and also to apply to the Royal Society, the Linnean Society and the Antiquarian Society of London . . . and other Societies to obtain duplicate books on Natural History and Science as contributions to the Library."

" His Excellency has further promised to write to the Secretary of State, to recommend similar contributions from the British Museum and other depositaries of learning and science in England."

1848 Report.—" A Museum, intended chiefly for objects in Natural History has been commenced. Already there is accumulated from various localities in the Island, many hundreds of specimens chiefly in the departments of Mineralogy and Geology. Among them are many valuable Fossils.

" There has also been placed in the Museum a considerable collection of Freshwater Shells from Massachusetts, North America."

1849 Report.—" Large additions have been made to the contents of the Museum and Library during the twelve months.

The rapid accumulation of objects (chiefly in the department of Natural History) in the Museum has made it necessary to expend a considerable sum in the purchase of cases. The same accumulation has rendered it impossible hitherto effectually to carry out a system of classification, or to complete the catalogue of specimens, as proposed. These, however, are points which will meet with early and special attention.

" The Council are bound thankfully to acknowledge that, upon an application made by the Society for aid towards the maintenance of the Museum, His Excellency the Lieutenant- Governor, in the exercise of his wonted liberality and desire to foster intellectual cultivation and social improvement, obtained from the Legislative Council a vote of £100 for 1849 and 1890 respectively.

" From this and other sources there has accrued a great accumulation of specimens of Tasmanian rocks and minerals. Presentations have also been made in the same department from Adelaide, New South Wales, and New Zealand.

" Considerable additions have been made to the collection of Shells in the course of the year; and the first on the list of contributors in this portion of the field stands the name of our late able and zealous coadjutor, the lamented Capt. Stanley.

" Insects have been promised, but as yet no collection has been actually deposited with us.

" Of Crustaceans but few have been acquired.

" Of Fishes and Reptiles a few only have been presented. The Council consider that the student in this portion of the field of natural history here will find paths but little trodden, and which, if pursued, will yield the most ample and interesting returns from time and attention bestowed: the subject is one which the Council earnestly recommends to such members of the Society as have inclination and opportunities for prosecuting it.

" Of Birds, a number of skins have been acquired by gift and purchase . . . The new cases recently filled up are intended for birds: already there is a considerable display of stuffed specimens.

" Of Mammals, few specimens have yet been obtained; skins of the brush kangaroo, the wombat, the kangaroo rat, the native cats, black opossum, etc., are in the cases.

" Presentations have been made of Medals and Coins of various ages and countries, and cases have been purchased for their reception.

" Articles illustrative of the manners and customs of Aboriginal inhabitants of the Islands of the Pacific and elsewhere, with other things curious or rare, have been received from sources too numerous to particularise."

In the Minutes of 22nd June, 1848, reference is made to the use of rooms provided by His Excellency the Governor. On 29th June, 1848, it was reported that His Excellency the President had allowed the Society the use of the sub-committee room at the Legislative Chambers for meetings and in which to place cases and drawers, &c., to form the nucleus of a Museum and Library.

1852 Report.—" The removal of the Society's museum and Library and of the meetings of members from the rooms now forming part of the suite occupied by the Legislative Council and which had heretofore been afforded rent free, for the purposes of the Society, to the Hall in Harrington Street, now held by the members of the Council in trust for the Society under a lease of five years, has thrown upon its funds a heavy annual charge. The rent is £60 a year . . . "

" The accommodation which has been secured cannot long however, prove adequate to the requirements of a Public Museum . . . "

" The Council considers that the first step should be to apply to the Crown for a grant of a suitable piece of land as a site, upon which, as a basis, then to proceed in raising, by public subscription or otherwise, a sum of money adequate to the speedy erection of so much of the plan of an extended edifice as the immediate and not very remote exigencies of the case may demand."

1853 Report.—" The Museum has received large accessions of specimens in the various departments of Natural History.

" The Council have also to intimate to members that His Excellency Sir William Denison has, in reply to an application made to the Government for the grant of a piece of ground suitable as a site for a new Museum, expressed his disposition and readiness to comply, provided the Society afford some guarantee that they will build within a reasonable time. It is the opinion of the Council, that, as National Museums are in all countries maintained for the sole benefit of the public, and at the public charge, the Legislature of Tasmania, when appealed to, will neither be slack to acknowledge its appreciation of the principle nor to follow the practice. But the Council consider that a subscription for the purpose of building should be set on foot and brought before the Legislature, as a proof that the Society carries public opinion with it."

* The Cottage was at the Botanical Gardens—built in 1829 it became later, the home of the Superintendent of the Gardens.

1854 Report.—" The Museum has attracted during the year, upwards of 1000 visitors . . . the Council would observe that, owing to the continued want of additional rooms, it is impossible to set up or expose to the view of the public a large proportion of the highly valuable and interesting objects in the possession of the Society."

[NOTE.—An earlier reference in the 1852 Report about the Museum removing to Harrington Street related to that year. The extract above from the report of 1854 which dealt only with matters of 1853 gives the quoted report of the Museum housed in Harrington Street.]

1855 Report.—" The Museum is now open to the public from 12 to 5 o'clock every day. Wednesdays and Sundays excepted. This arrangement, involving the constant presence and permanent payment of an attendant, entails a considerable charge on the funds of the Association, as will be seen by reference to the Balance-Sheet.

" Mr. Milligan has placed in the Museum the whole of his very extensive private geological collection, with a view to its arrangement and separation, and the assignment of a complete series of specimens to the Society. To meet the exigencies of so large an accumulation of specimens in the several departments, the Council have, at a heavy cost, enlarged the means of shelf and case accommodation, by cases purchased from the Trustees of the Franklin Museum* at New Town. Still, there is a very obvious deficiency of space in which to effect a systematic classification of the contents of the Museum, or even to dispose of them so as to produce a popular effect, or one pleasing to the eye.

" The Council, therefore, feel once more called upon to stir up to exertion the friends of the Institution in behalf of larger, more perfect, and permanent accommodation. Few places are better calculated, they still think, for the site of a Museum, conjoined with Zoological Gardens, than the open plot of ground in Fitzroy Crescent, already assigned to the Society for building upon. As labour falls in price, it may be worth consideration whether, if the money for such a purpose were raised in shares, say of £10 each, the Legislature, regarding the Institution as strictly of a public and educational character, may be found willing, if not to contribute directly towards the erection of the edifice, at least to guarantee upon a building capital so produced a moderate rate of interest for 20 or 25 years, upon the understanding that the Society would devise means for paying off a portion of the liability so incurred periodically; say one-fifth every five or six years.

" The Council, has however, reason to believe that the Legislature will directly contribute to an object so valuable and so truly national a sum from the public funds more than equal to any amount raised by public contribution for the purpose; they therefore consider that steps ought immediately to be taken for obtaining subscriptions to be used as a basis for further proceedings—the limited amount of accommodation afforded by the building at present occupied precluding any delay that can be avoided."

1856 Report.—" With reference to the views propounded in the Reports for the last and previous year, touching the urgent and pressing necessity then existing for additional accommodation, and the best means of attaining it in the shape of a new Museum,—the Council, while they express anew their increasing anxiety on the subject, consider that, under present circumstances, they will best further the object by laying before the general body of Fellows the following Correspondence which has passed with the Government on the subject:—

" Royal Society of Tasmania,
Hobart Town, 22nd May, 1856.

SIR,—I am directed by the Council of the Royal Society to solicit the attention of His Excellency the Governor and Local Government to the present position, claims and requirements of the Museum. The amount of accommodation enjoyed by the Society for the purposes of a Museum and Library, and for meetings of the Society and the Council, limited to one large room, has been found for a considerable time past altogether inadequate to the urgent and rapidly increasing requirements of the Institution. The cases and fittings in the Museum are without exception filled to repletion with specimens and books, and with their contents are insured against fire for £2,000,—a sum much below their actual value, indeed, twice the amount would not replace them, were such an untoward mishap as their destruction by fire to occur.

" I am directed to remark that the contents of a Museum ought not to be subjected to the losses, mischances, and injuries incident to a removal from one building to another, and that wherever such an Institution has been established and grown into national importance, it has found a fixed and permanent habitation under the auspices and at the expense of the State.

" I am to inform the Government, through you, that while a heavy rent is now being paid by the Royal Society for the premises occupied as a Museum in Harrington-street, the accommodation afforded is too narrow to allow of the proper classification, arrangement, and display of the specimens already collected; that this circumstance operates prejudicially to the prospects of the Institution, and most materially abates from the advantages to be otherwise derived from it by the community; and that, inadequate as the present accommodation is, there is no security even for its continuance for any lengthened period, as the lease held by the Society will shortly expire.

" I am further to say that, although the Members of the Society are unanimous in the opinion that additional accommodation is now indispensible, all are not agreed that either of the localities (Fitzroy Place and the Government Domain), which have at different times been selected, is suitable for an Institution to which the Public ought to have the freest possible access. . . .

" I am therefore, on the part of the Council of the Society, to submit to the Government, that as the erection of the Museum will be exclusively for the benefit of the Public and its contents remain for ever an accumulating public property, the cost of the work ought to be defrayed here, as in other countries, from the public purse, and that the Crown (Her Most Gracious Majesty the Queen is the Patron of the Royal Society, under whose auspices the Museum originated), ought in the legitimate exercise of its prerogative, to grant in some central situation in the city a site for the structure, in which case a commodious and symmetrical plan, upon a scale calculated to subserve all purposes for a few centuries to come, would be at once prepared, with a view to its progressive execution as the necessity may arise, so as to secure ultimately, with convenience as regards space, consistence in arrangements and architectural effect.

" Having stated the grounds upon which the Council and Members of the Society have formed the opinions and views they entertain, I am to request that you will move His Excellency the Governor to place on the Estimates for the ensuing year such a sum (and it is thought that less than £3,000 would not suffice) as may be adequate to the erection of so much of a building, for the purposes of a National Museum, as is required at the present time, to be open to the Public under due regulations, and to be for ever vested for such purpose in the Trustees of the Royal Society as now recognized by law.

" I am at the same time to request, with a view to effectuate this object with greater certainty, and in a way to render the Institution convenient to the community, and to secure from it the utmost attainable amount of public good—that you will move His Excellency to grant a piece of Crown land for a site in one of the following situations:—At the corner formed by Macquarie-street and Murray-street, in the quadrangle enclosed by the wall of the gaol, which it is understood will very soon be removed; or at the corner formed by Macquarie-street and Argyle-street, now garden-ground, occupied by the Aide-de-Camp; or in Collins-street, upon a piece of ground between Elizabeth-street and Murray-street, the property of the Crown, which is now occupied as a Coachmaking Establishment. . . .

I have the honour &c.,

JOSEPH MILLIGAN."

The Hon. the Colonial Secretary,

" Colonial Secretary's Office,
10th June, 1856.

" SIR,—I have laid before the Governor your letter of the 22nd ultimo, soliciting, on behalf of the Royal Society of Tasmania, the grant of a site in Hobart Town for a Museum and of a sum of money from the Public Revenue in aid of its erection; and in reply I am to acquaint you that it is con-

* The reference to the Franklin Museum in New Town concerns the building erected through the interest of Lady Franklin, wife of Governor Sir John Franklin. An account of this charming piece of Greek architecture is given in the booklet " Souvenir of Lady Franklin Museum, Hobart "—*Mercury* Press, 1949.

templated to pull down the present gaol*, and that His Excellency will be glad to reserve a portion of the site on which a Museum may be erected; and further, that he is disposed to entertain favourably the application for a grant of money, but before such a matter can be submitted to the Legislature, plans of the building to be erected should be prepared and approved.

"His Excellency is of opinion that the Tasmanian Public Library has an equal claim with the Royal Society to the consideration of the Government, and he desires me to request that the plans which you procure shall embrace accommodation for the Public Library, and also that no time may be lost in their preparation."

I have the honour to be, Sir,
Your very obedient Servant,
W. CHAMP."

February 9th, 1859.

"Letter from the Hon. the Colonial Treasurer dated 22/1/1859 notifying the reserve of land near the old Government House as a site for the new Museum and stating that the same would appear in the Gazette."

"The Gazette of 29th January contained the notice of the Museum laid on the table."

August 10th, 1859.

"Secretary reported having received and deposited in the Commercial Bank upwards of £1,400 being subscriptions for the erection of a new Museum and that promises to more than the sum of £1,500 have been obtained."

As a result an approach was made to the Hon. the Col. Treasurer claiming payment of £3,000 granted by Parliament last session on condition of £1,500 being raised for the erection of the building by public subscription.

"Resolved that the sum of £1,500 having been raised by subscription to aid in the erection of a new national museum in terms of the Act of Parliament 22 Victoria No. 36 which on this condition grants a sum of £3,000 to be applied to the same object the time has arrived when the building about to be commenced and the work vigorously prosecuted and that an application ought therefore to be at once made to the Colonial Government for the immediate issue of a grant from the Crown of the ground assigned as a site for the same as notified in the Gazette under date 22/1/1859.

"Resolved also that the Secretary do accordingly address a letter to the Colonial Government requesting the issue of such grant in the name of the members of the Council of the (Royal) Society, they being Trustees as defined in the Royal Society Act 18 Victoria No. 4."

1860 Report—"The Council have succeeded in obtaining from the Government a good site† for the New Museum and upon invitation several designs have been furnished for the new building. These will be exhibited at the Annual Meeting and afterward for a week to the public after which the decision of the Council as to their relative merits will be announced."

Extracts from Royal Society Minutes.

January 4th, 1861.

Period for sending in designs extended to 28th January.

January 29th, 1861.

Designs for new museum sent in by "Fides", "Nimrod", and "Utility" we have examined, and directions were given for exhibiting them to the public for a week.

February 9th, 1861.

1st prize given to design submitted by "Nimrod".
2nd prize given for 2nd best of drawings submitted "Utility".

May 8th, 1861.

8 tenders received for erection of proposed Museum in Macquarie Street.

Firm	Tender	Time
Anderson & Sockie	£4625	8 months
J. Gregory	£4490	—
W. Andrews	£4350	10 months
Young & Williams	£4120	—
J. Rait	£3700	14 months
A. M. Nicol	£3075	—
Seabrook & Son	£3580	12 months

Resolved to accept tender of Seabrook & Son.

It was discussed whether it would be desirable to complete the plan of the museum in Argyle Street, the tender of Messrs. Seabrook & Son being so much within the funds of the Society for the building, but it was thought better to leave the surplus amount to meet unforeseen expenses and the cost of fittings for the new museum.

August 12th, 1861.

A committee of Mr. Lewis, Mr. Archer and Dr. Agnew was appointed to make arrangements for laying the Foundation Stone of the new Museum on Saturday next 17th instant at 3 p.m.

August 17th, 1861.

Minutes of a special meeting of Council at the Museum convened for arranging and attending the ceremonial of laying the first stone of the new museum by his Excellency the Governor. (Sir H. E. Fox Young, C.B.)

. . . Mr. H. Hunter, architect of the proposed new museum then produced the inscription, engrossed in vellum, which with the newspaper of the day were enclosed in a bottle. It was then determined that the Council should adjourn to the site of the new Museum, there to receive the Governor in a Body.

The Council then adjourned to the site of the New Museum where His Excellency, Sir H. E. Fox Young, C.B. performed the ceremony of laying the corner stone with the usual formalities.

1861 Report—"A design has been procured (for the building of a commodious Museum and Library) by public competition, contracts have been entered into, and the more substantial parts of the building erected."

1862 Report—Meeting held at the Museum, Macquarie Street at 7 p.m., 29th January, 1863.

"It now only remains for the Council cordially to congratulate the Fellows on this their first Meeting within the walls of their New Museum. The tenure of the old Museum having expired at the close of 1862, its contents have been removed to this building, but are in a temporary state of confusion pending the completion of the exhibition cases. It having been found that the Building Fund was not quite adequate to the completion of the internal fittings, the Council determined to hold for a few weeks an Art Exhibition, with the view of adding to the Fund such a sum as would suffice for this purpose, it being determined, if possible, not to trench upon the resources of the Society. The Exhibition has been most ably and artistically carried out by Mr. Morton Allport, Captain Chesney, and Mr. Hunter, and, as they anticipate that the sum required will thus be realised, we expect in a few weeks to commence the scientific arrangement and classification of our very valuable books, and stores of objects, and specimens of Natural History etc. In the Geological department we shall have the invaluable assistance of Mr. Gould, the Government Geologist; the Rev. T. J. Ewing has kindly undertaken to superintend the classification of the Birds, etc., and for the general arrangements we have secured the services of Mr. Robin, who has long been accustomed to similar duties in Museums in London, and who, on the resignation of Mr. Whiting, in July last, was appointed as his successor at the same salary.

"On the whole we may anticipate that our Museum, when completed, will be an ornament to Hobart Town, a credit to Tasmania, and invaluable as a field for study and reference on almost every subject connected with the Natural History and production of the Colony.

[NOTE.—In Reports and Minutes there is no note of the definite date on which the Museum as such was opened. The Art Exhibition mentioned was held in one room but as there was no money for display cases, and as the Harrington Street premises had to be vacated by the end of December 1862, exhibits and material belonging to the collections were scattered on the floor in the various rooms. The Minutes indicate that members of the Council were distressed to see the rooms in such a state and they agreed to take action to collect money to provide adequate show cases to get the Museum opened as soon as possible. It is presumed this is why the report of 29th Jan. 1863 states ". . . our Museum when completed . . ."."]

* The gaol was then situated at the corner of Murray and Macquarie Streets and diagonally opposite St. David's Cathedral.
† This site is the one on which the present building stands.

1872 Report—"Many specimens of our Mammals, Reptiles, etc. have been added to our collection, and others as a means of affecting exchange with other Museums have been of special value. The Native Tigers (*Thylacinus cynocephalus*) have been particularly useful in this respect, special requests have been received from Adelaide and Christchurch, New Zealand."

1885 Report—"The Museum has undergone a change of government, in accordance with an Act passed during the recent session of Parliament. Having by that Act been incorporated, it is now a national institution, with an annual endowment of £500. The management of its affairs is vested in a Board of Trustees, consisting of five officials, a Crown Trustee named by the Governor, and six others elected from the Council of the Society.

"The fact that the Museum has thus for the first time been placed on a secure and permanent basis will unquestionably exert a happy influence over its future development. The number of visitors have been very large, including temporary residents from other colonies and passengers by the various steam routes who make a short stay on their way to and from New Zealand."

[Note.—From this date, all extracts are from the Minutes meetings of Board of Trustees of Tasmanian Museum and Art Gallery.]

Extract from Act dated 5th December, 1885.

"Whereas the Museum situated in Hobart and known as 'The Royal Society's Museum' has been for many years in the possession of and under the control of 'The Royal Society of Tasmania for Horticulture, Botany and the Advancement of Science' the Society has acquired a large collection of specimens of Natural History and other objects of value, which collection is now deposited in the said Museum and is the property of the Society; and whereas the Gardens situated in the vicinity of Hobart and known as 'The Royal Society's Gardens' . . . ; and whereas the Society has proposed to surrender all claims to the Museum . . . and to the Gardens . . ."

Trustees, 1st Meeting Jan. 29th, 1886.

The Chief Secretary (Sir Adye Douglas) was elected to the Chair. Mr. Alex. Morton was appointed Curator and Secretary to the Tasmanian Museum and Secretary to the Gardens. Salary as Curator £200 with residence, gas and fuel etc. and as Secretary £50 p.a.

At that first meeting Mr. J. M. Arnold was appointed Caretaker and Messenger and Mr. F. Abbott was appointed Superintendent of the Botanical Gardens at a salary of £200 p.a. Hon. J. W. Agnew was appointed Treasurer.

July 1st, 1886.

"A letter was received from the Chief Secretary stating that the plan of the new wing to the Museum had been submitted to Cabinet and approved.

"Because of obscene writings appearing frequently in the Visitors Book recommended that the book be discontinued."

September, 1886.

"A letter received from the President of the Mechanics Institute, Launceston stating that they were desirous of forming a Museum in Launceston and as a room has been recently set apart for that purpose they were desirous that leave of absence might be granted to Mr. Morton so that he might arrange the collection for them. Leave of absence as suggested was granted . . ."

May 5th, 1887.

Letter from Hon. the Minister for Lands and Works stating that with the concurrence of His Excellency it had been decided to hand over the cottage hitherto known as the Private Secretary's cottage to the Trustees of the Tasmanian Museum and Botanical Gardens as a residence for the Supt. of the Botanical Gardens. Trustees accepted.

November 3rd, 1887.

Curator reported "that he had that day received a fine specimen of *Salmo sp.* caught in the Huon by his Excellency* and presented by him to the Museum. The fish weighed 29 lbs., length 35 inches and girth 26 inches.

June 5th, 1889.

Curator reported that on 22nd ult the new wing had been officially opened by his Excellency. (Sir R. G. C. Hamilton.)

January 31st, 1890.

"In reply to a letter from the Royal Society of Tasmania to the Government of May 9th, 1888, requesting that the Island known as Franklin Island might be vested in the Trustees of the Society, the Government forwarded a large number of letters bearing on the subject and informing the Board of Trustees that they would be prepared to accede to the request."

December 30th, 1890.

"Letter from the Mayor of Launceston on behalf of the Municipal Council of that City requesting that the Curator's services as Curator to the Victoria Museum and Art Gallery of Launceston might be granted. The Curator (Mr. Morton) stated that the duties in connexion with the Launceston Museum would not take up a great deal of time as a caretaker was to be appointed who would take his instructions from Mr. Morton and it would be necessary once or twice monthly to visit Launceston. The Trustees thought it would be highly desirable to assist the Northern Museum and that if agreeable to Mr. Morton the approval of Trustees would be freely granted."

July 5th, 1892.

"The Curator stated that as several applications had been received from the different Museums asking for specimens of Native Tigers, and not having many in duplicate, he had met the Minister of Lands who had informed him that if the Trustees would pay a pound a head he would instruct the different wardens to forward specimens when brought to them for the Government reward, to the Museum.

The Curator was instructed to thank the Hon. the Minister and inform him that they would be prepared to pay the sum asked for, for a limited number of 15, provided they were good specimens."

July 31st, 1893.

"Letter from Mr. Alfred Mayson, Bicheno, informing the Curator that he had been able to secure the skull of a Tasmanian female aborigine, the name of the native being 'Wauba Debar', died June, 1893, aged 40 years. Mr. Mayson promised to forward the skeleton by the next trip of the 'Warrentinia'."

Small note which says,

"Here lies Wauba Debar,
female aborigine
of Van Diemen's Land.
Died June, 1893
Aged 40 years.

This stone is erected by a few of her white friends."

[Note.—No reference to situation and stone, etc.]

October 4th, 1898.

"In view of the expected arrival of the Antarctic Expedition on the way to the South Pole, the Government be asked to co-operate with the Trustees of the Museum and the Council of the Royal Society in arranging a reception to be given to the Leader of the Expedition, Mr. Casten Borchgrevink, F.R.G.S., and the members of the scientific staff on board the 'Southern Cross'."

September 19th, 1899.

"The Bishop of Tasmania wrote stating that he came across on Vansittart Island (Furneaux Group) the graves of 17 Tasmanian Aborigines buried there by G. A. Robinson. Curator was authorised to examine the site with a view of securing the skulls and skeletons and the Chairman undertook to write to the Chief Secretary for permission to examine the bodies."

June 10th, 1906.

"The Director drew attention to a discovery of a number of bones that had been obtained on King Island among them had been determined as belonging to an extinct Emu. This recent discovery was of great scientific interest . . ."

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* Sir Robert Hamilton.

December 23rd, 1907.

Col. W. V. Legge wrote saying that two skins of the Tasmanian Emu had lately been found and placed in the National History Department of the British Museum.

March 6th, 1911.

"The Chairman . . . informed the meeting that the Thlyacine was still a plentiful animal in certain parts of the country."

July 2nd, 1917.

The action of the Chairman and the Hon. Curator in purchasing a live Tasmanian Tiger for £15 was approved.

April 12th, 1920.

"The Curator reported that a *Nototherium* had been discovered in the Mowbray Swamp and that it was extremely probable that this specimen would be obtained for the Tasmanian Museum."

May 31st, 1920.

"The *Nototherium* specimen was to be described in the Papers and Proceedings of the Royal Society of Tasmania by Messrs. Scott and Lord . . .

"Resolved to write to the Premier asking that action be taken by the Government to prevent the exportation from Tasmania of valuable natural history specimens."

July 30th, 1926.

"Director reported he had purchased a Thylacine specimen for £10."

April 2nd, 1928.

"Committee wished to draw attention to the fact that within the last 2-3 years, mutton birds had commenced to breed on Franklin (Betsey) Island . . . the Trustees might consider the advisability of ceasing to lease the Island and of having it declared a sanctuary."

May 7th, 1928.

Reported that English blackbirds had been seen in the vicinity of the gardens and that the Government fruit experts hoped to have the birds exterminated before they became a pest."

May 31st, 1935.

"Reported that a set of casts of the aboriginal rock carvings at Mt. Cameron West was being made at the Adelaide Museum and would be presented to the Tasmanian Museum and Art Gallery."

April 6th, 1936.

"Two Wainewright watercolours purchased for £10 each."

April 8th, 1937.

"A letter was read from the Chief Veterinary Officer, Department of Agriculture to the effect that it was proposed to make experiments on the control of rabbits by the disease Myxomatosis and in this connexion enquiries were being made to ascertain the views of the Trustees regarding Franklin Island. In case it was decided to conduct experiments on this island the Trustees agreed that permission would be given to do so."

In 1950 it was agreed that the Botanical Gardens and the Museum should act under separate Boards of Trustees. Both had been started by the Royal Society of Tasmania, both had been administered by the Council of the Royal Society with a separate committee, for each institution.

A new Act was prepared for the Tasmanian Museum and Art Gallery and this came into operation in 1952 as did the new Act for the control of the Botanical Gardens.

Museum Directors.

1860-1861	J. Whiting—Curator.
1862-1884	Thomas Roblin—Curator.
1884-1907	Alexander Morton: 1886-1903—Curator; 1903-1907—Director.
1908-1912	Robert Hall—Curator.
1912-1918	Professor T. T. Flynn, D.Sc.—Acting Curator.
1912-1917	G. Hardy—Assistant Curator.
1918-1933	Clive Lord: 1918-1922—Curator; 1922-1933—Director.
1934-1952	Joseph Pearson, D.Sc.—Director.
1953 (Jan.-June)	R. Colbron Pearse, Acting Director.
1953?	William Bryden, C.B.E., Ph.D.—Director.

The following sources of information and references were used in preparing this brief history:—

PIESSE, E. L.—*The Foundation and Early Work of the Society.* Royal Society of Tasmania Publication, 1913.
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Papers and Proceedings of the Royal Society of Tasmania, Volume 100

MYTILOCYPRIS, A NEW OSTRACODE GENUS FROM TASMANIA

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(With one figure.)

ABSTRACT

Mytilocypris tasmanica, a new cypridid ostracode genus and species (subfamily Cypridinae, tribe Eucypridini), is described.

INTRODUCTION

During the Australia and New Zealand Association for the Advancement of Science Meeting in Hobart (August, 1965) the opportunity was taken to sample from nearby lagoons and ponds and from the Derwent River. One of the samples, from Calverts Lagoon, a body of shallow, brackish water on the South Arm peninsula, about 19 road miles from Hobart, yielded a population of an unusually large ostracode which upon inspection has proved to be a new genus and species.

The population sampled consisted of 81 individuals, including both males and females, ranging in size from 0.6 mm to 4.0 mm, representing several moult stages of the one species. The size range most frequently encountered was 3.3-3.6 mm (54 individuals), and only 6 individuals were true adults (3.8-4.0 mm), i.e. fully developed males and ovigerous females. Of the rest, 12 individuals were in the 2.4-2.6 mm range, 6 individuals in the 1.6-1.8 mm range, 2 individuals in the 1.1-1.2 mm range, and a single individual measured 0.6 mm.

Two individuals 3.3 mm in length (one male, one female) and two others nearly 4.0 mm long (also one male, one female) were dissected. The description below refers to the larger series.

Systematic Description

Subclass	Ostracoda	Latreille, 1806
Order	Podocopida	Müller, 1894
Family	Cyprididae	Baird, 1845
Subfamily	Cypridinae	Baird, 1845
Tribe	Eucypridini	Bronstein, 1947
Genus	*Mytilocypris* n. gen.	

Type species: *Mytilocypris tasmanica* n. gen., n. sp.

Derivation of name: mytilus (Lat.) = a mussel, and generic name *Cypris*.

Diagnosis: Subtriangular eucypridinid; dorsal margin sloping backwards, posterodorsal margin inflexed, posterior subacuminate in contrast to the broadly rounded anterior, ventral margin almost straight; left valve larger than right valve; surface of valves smooth or micropunctate with peripheral hairs, and pigmented (brownish-yellowish, with green zebra-like markings to deep greenish); size large (adults more than 3 mm long in the known species); greatest height anteromedial; dorsal view elliptical, slightly compressed anteriorly; selvage marginal in both valves; inner list prominent in both valves, upraised more in the larger left valve than in the right valve; inner lamellae broad both anteriorly and posteriorly; radial pore canals numerous, short, usually branched; normal pore canals scattered, small, open; ridge and groove hingement; muscle scars comprising an adductor cluster (of five large and three small scars in the type species) with large mandibulars in front and below this, and small antennal scars in front and slightly above, and several dorsal scars. Anatomically, the genus appears to be characterised by more slender first antennae than other eucypridinids and by a single or double row of small spines on the posterior margin of each furcal shaft. Further, the left and right prehensile palps of the male second maxilla appear to differ less from each other in this genus than in other eucypridinids, and the chitinous ejaculatory process contains a very large number of rosettes.

Remarks: This genus resembles in shape several genera in the subfamilies Paracypridinae Sars, Pontocypridinae Müller, Dispontocypridinae Mandelstam and Clinocypridinae Mandelstam but in this respect is unlike any genus in the Cypridinae. Anatomically, however, and in its size and such *internal* shell features as the prominent inner list and the muscle scars, it is undoubtedly a member of the Cypridinae (tribe Eucypridini). It populates a littoral lagoon resembling environments in which such genera as *Propontocypris* Sylvester-Bradley and *Phlyctenophora* Brady could reasonably be expected to occur at higher salinities (>15°/oo) and thus is a good example of morphologic convergence possibly due to gross similarities in habitats.

Mytilocypris tasmanica n. sp.

Derivation of name: from the state in which this species was collected

Type Material:

Holotype; adult ovigerous female; Australian Museum Number P 15016

Paratype; adult male; Australian Museum Number P 150117

Syntypes; male and female, 1st stage, Tasmanian Museum Accession Numbers G 1160 (♂) and G 1161 (♀)

Description: Carapace large; subtriangular in shape; margins as in generic diagnosis; surface smooth with peripheral hairs; colour of the valves deep olive green, anatomy greenish dark brown in colour, ova varying from orange to bright yellow, after some time in alcohol the colour of the valves changes to dark bluish green; greatest height anteromedial, at about one-quarter of the length from the front, and little less than half the length in both sexes; in dorsal view as described for the genus, greatest breadth medial and about one-third the length. Internally: lamellae broad anteriorly and posteriorly but narrow ventrally; selvage marginal; zone of concrescence narrow throughout; radial pore canals as in the generic diagnosis; inner list prominent; duplicature apparently smooth between inner list and line of concrescence, but distinctly reticulate between inner list and inner margin; list itself transversely striated (especially noticeable in the right valve); normal pore canals as in the generic diagnosis, more numerous anteriorly and in the postero-ventral corner; hingement consisting of a ridge in the right valve (most prominent antero-dorsally and near the beginning of the postero-dorsal inflexure) which fits into an accommodation in the larger, overlapping left valve; muscle scars comprising a subcentral adductor cluster of five large and three small scars, with two large oval mandibulars in front and below this main group, and two small antennal scars in front and slightly above it and at least six dorsal scars. Anatomically: the length: height ratios of the 3rd to 7th joints of the 1st antenna are 20:5, 10:4, 8:3. 6:2, 4:1.5 in both sexes; natatory setae of the 2nd antenna reach almost to the tips of the claws, exopodite of the 2nd antenna a small plate bearing 2 or 3 unequally long bristles, barbed bristle of the male 2nd antenna very strong measuring 350μ; epipodial appendage of the mandible has one medial and five distal strahlen in both sexes, but in females carries in addition a small distal bristle, coxale of the mandible very strong, masticatory process reddish brown in colour, with a short stout anterior bristle and two short curved posterior bristles, the two bristles between the 1st and 2nd molars are both serrate as is the longer bristle between the 2nd and 3rd molars, there are seven molars in all which decrease in strength from front to rear; lobes of the first maxilla elongate-cylindrical, 3rd lobe with two Zahnborsten (toothed bristles), palp with an elongate distal joint (length: height ratio, 2:1), epipod with about 20 strahlen; palp of the 2nd maxilla different for the two sexes, in females consisting of a lobe bearing three bristles, the two shorter bristles approximately equal in length, the third about 2½ times their length, in males the palps are prehensile and rather similar although the left palp is less strongly curved than the right palp, the posterior lobe in both males and females bears thirteen pilose bristles, the epipod in both sexes carries five strahlen; 1st leg bearing two smooth bristles on the geniculate 2nd joint with 5 small dorsal spines and one ventrodistal bristle on the 3rd joint, 4th and 5th joints fused, ventrodistal bristle of the 4th joint much longer than the 5th and 6th joints combined, 5th joint with two unequal ventrodistal bristles, 6th joint small with 2 distal bristles (one ventral, the other dorsal), claw long, slender, curved, pectinate, length:height ratios of the 3rd to 6th joints are 21:8, 12:5, 13:4, 3:2.5; 2nd leg with a small distal joint bearing two setae, one of these hook-shaped and annulate, penultimate joint elongate and slender; furca well-developed, 800μ long, with two claws and two bristles, the anterior bristle 5/6 the length of the posterior bristle the anterior claw 5/3 the length of the posterior claw and four times longer than the anterior bristle, both claws pectinate, posterior margin of the furcal shaft adorned with a double row of short spines extending from the posterior bristle almost to the proximal end of the shaft, in addition the furca is adorned with several scattered hairs; male ejaculatory process with about 60 chitin rosettes; male penis as illustrated and about 960μ long.

Dimensions: Holotype, female: length 3.9 mm, height 1.85 mm, breadth 1.30 mm. Paratype, male: length 3.8 mm, height 1.80 mm, breadth 1.20 mm.

Type locality: Calverts Lagoon, South Arm, near Hobart, Tasmania.

Distribution: Tasmania.

Discussion: This distinctive genus appears to be endemic to southern Australia. In 1886, G. S. Brady described *Cypris mytiloides*, which was "collected by Professor R. Tate in fresh water, at Kangaroo Island, Australia". This South Australian form undoubtedly belongs in the same genus but is specifically distinct since it is about 20% larger, differently pigmented ("Colour in life light brown, with darker zebra-like markings". Professor R. Tate in G. S. Brady op. cit. p. 90), and has a furca which bears only one long claw instead of two claws as in *Mytilocypris tasmanica* (according to the type illustration). Recently, I. A. E. Bayly collected a species which is probably identical with Brady's, from a swampy lagoon (salinity 0.3°/oo) near Kilcunda, Victoria, close to the mouth of the Powlett River and only separated from the sea by a dune (I. A. E. Bayly personal communication). This Victorian form has similar markings to Brady's species and is of the same size, but differs in in that there are two claws on the furca. However, Brady's specimen may have been damaged prior to illustration and, as the type appears to be lost, the collection of further topotypes from Kangaroo Island will be necessary to decide whether or not the Victorian and South Australian forms belong to the same species. The Victorian species differs from the Tasmanian type species in at least the following anatomical characters, apart from its greater size and distinctive shell markings; there is only one posterior bristle on the masticatory process of the female mandible coxale; there are a single pilose bristle and a clump of hairs on the geniculate 2nd joint of the 1st leg, and only 4 small dorsal spines plus a ventrodistal bristle on the 3rd joint of this limb; it bears only a single row of small spines on the posterior margin of the furca, and the anterior furcal claw is twice the posterior claw in length; further the length:height ratios of joints in general are dissimilar.

No other species referrable to the genus are known to me, with the possible exception of one collected at Rottnest Island, W.A. (Chapman personal communication).

ASSOCIATED FAUNA AND SALINITY

Other ostracodes in the sample were *Gomphocythere* sp. and *Ilyocypris* sp., both probably new but represented only by single specimens. The associated fauna included the copepods *Boeckella triarticulata* (Thomson) and *Microcyclops arnaudi* (Sars) (I. A. E. Bayly personal communication), the amphipod *Austrochiltonia australis* (Sayce) (W. D. Williams personal communication), and a gastropod, *Coxiella* sp., the latter in great abundance on the supralittoral margin. The concentration of total dissolved solids in a water sample collected at the same time was about 6.8°/oo, which is equivalent to a salinity of about 6°/oo. This is the highest value recorded for the concentration of total dissolved solids from Calverts Lagoon for which the range in T.D.S. was previously known to be 3.52-4.25°/oo. (W. D. Williams personal communication in Bayly 1964, p. 236). It is likely to be the upper limit of *Mytilocypris'* salinity tolerance, in view of the data provided by Bayly for the Victorian species, and the lower salinities recorded previously from Calverts Lagoon.

ACKNOWLEDGEMENTS

The research has been carried out during tenure of the inaugural Shell Research Fellowship for Monash University at the Department of Zoology and Comparative Physiology. Grants-in-aid have been made by Delhi Australian Petroleum Pty. Limited, Mobil Exploration Pty. Ltd. and Alliance Oil Management Pty. Limited. Drs. I. A. E. Bayly and W. D. Williams reviewed the manuscript. Charles McCubbin inked my original drawings, and Miss G. Meredith typed the final manuscript.

Holotype and paratype are located at the Australian Museum, Sydney; syntypes at the Tasmanian Museum, Hobart.

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Fig. 1 [See next page.]

Fig. 1.—*Mytilocypris tasmanica* n. gen., n. sp., holotype, adult ♀, Aust. Mus. No. P 15016: *1.* Internal view, right valve; *2.* Dorsal view of carapace; *3.* Ventral view, left valve; *4.* Epipod of the mandible; *5.* 3rd-7th joints of the first antenna; *6.* Detail of bristle between 1st and 2nd (anterior) molars on mandible coxale; *7.* Detail, radial pore canals, anteroventral region of right valve; *8.* Lobes of the 1st maxilla; *9.* Endopodite joints and coxale of mandible; *10.* Palp of the 1st maxilla; *11.* Distal 2nd antenna; *12.* Proximal 2nd antenna; *13.* Zahnborste of 3rd lobe of 1st maxilla (detail); *15.* 2nd maxilla; *17.* Proximal 1st leg; *18.* Furca; *20.* Distal 1st leg; *21.* Distal 2nd leg (detail); *23.* Second leg; paratype, adult ♂, Aust. Mus. No. P 15017; *14.* Palp and lobes of 1st maxilla; *16.* Left palp, 2nd maxilla; *19.* Right palp, 2nd maxilla; *22.* Penis. Magnifications: 1-3 × 20 approx.; 4, 5, 7-12, 14-20, 22, 23, × 65 approx.; 6, 13, 21, × 150 approx.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 100

THE BREEDING OF THE BLACK SWAN (CYGNIS ATRATA LATHAM) IN TASMANIA WITH SPECIAL REFERENCE TO SOME MANAGEMENT PROBLEMS

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(With four plates and seven text figures.)

ABSTRACT

The breeding distribution of the Black Swan in Tasmania is given and the breeding history of the species over three years in the principal breeding area at Moulting Lagoon is described. The incubation period was found to be 39± 2 days and cygnets fly 60 days after the appearance of juvenile plumage. Floods are the main source of egg mortality and other factors are relatively unimportant. Direct observation and statistical calculations were used to estimate the annual cygnet production. The statistical methods gave widely divergent estimates. Shooting over the breeding ground has an adverse effect upon breeding, upsetting pair formation. Restriction of this shooting has resulted in a greater cygnet production. Flooding and autodestruction of habitat are important factors in breeding success and recommendations for the management of the species are given.

INTRODUCTION

Much work has been done on the biology of the Anatidae of the world and particularly upon ducks and geese in relation to management problems. These birds are the subject of considerable hunting pressures and the emphasis in the programme is placed upon the maintenance of the populations.

Swan management problems in many other parts of the world are associated with the maintenance of populations which may be reduced to such numbers as to be a threatened species, e.g., Whistling Swan of North America. However, the New Zealand (Oliver, 1955, Miers, 1962), Victorian and Tasmanian problems relate to the shooting of relatively large populations both for sporting purposes and as a control.

STATUS OF THE BLACK SWAN IN TASMANIA

The Black Swan, *Cygnis atrata* (Latham) is widely distributed throughout much of the Australian continent including Tasmania and is established in a successfully breeding feral state in New Zealand. The species is well known in zoological collections readily adapting itself to captivity.

Black Swans are found generally throughout Tasmania on most lakes and large ponds. Many birds live and feed in salt or brackish water while others are found living and feeding in freshwater conditions. The birds usually occur in aggregations from a few pairs to several hundreds, though only one pair may be found occupying small waterholes. The number of Black Swans encountered on any one area of water appears to be controlled by the availability of food though during drought conditions the number of birds on certain waters may greatly exceed the carrying capacity of the area. Under these conditions the available food is soon reduced and the birds are forced to feed ashore.

The number of Black Swans in the early days of white settlement clearly was very great as all the diaries and journals record this feature. Since then it is apparent that the swan population has decreased although no actual counts are recorded. Lord (1927) noted thousands of Black Swans in Port Davey while Green and Mollison (1961) found only 200 and this count appears to be about the maximum found there as shown by aerial survey flights carried out annually for a period of four years.

The Black Swan population is influenced by the success or otherwise of breeding, since the nesting sites are especially prone to flooding. A series of adverse years will result in small year groups but in a species of the longevity of the Black Swan this, together with other short term factors, will tend to even out over a long period.

The greatest influence on Black Swan numbers is the pressure of human activity with habitat alienation and alteration as the major factors and shooting as a locally important subsidiary. The Black Swan was the subject of annual seasons of 3 months but diminution of the population in the 1930's led to the closure of the season and it was not until 1958 that the season was re-opened, although for a shorter period of time and with bag limit restrictions.

Swan shooting is carried out in restricted areas of Tasmania, notably at Moulting Lagoon where the majority of shooters congregate. Thus most of the shooting pressure is exerted upon the East Coast population of Black Swans. The Moulting

Lagoon area is the principal breeding site in Tasmania and the present investigation was carried out to ascertain some of the basic data for the development of a game management programme for this species in Moulting Lagoon. In particular, emphasis has been laid on the breeding of the Black Swans and the relevant general biological data. Observations were made during the 1960-1964 breeding seasons and at other times of these years and specimens were collected regularly during 1960 for laboratory examination.

METHODS

Emphasis was laid on the examination of the factors affecting breeding during the 1960 and 1961 breeding seasons. Eggs were marked and dated during daily visits to the nests which were also marked. The total number of eggs laid in Moulting Lagoon was counted as was the total number of cygnets hatched. Brood sizes were counted from the air and a cygnet mortality figure calculated. During the 1962-64 seasons the total number of eggs laid was counted and the percentage hatch estimated from later counts.

The present paper describes the 1960-62 breeding in detail and comparisons are given for the 1963 and 1964 seasons.

PRINCIPAL BREEDING SITES

Breeding takes place at many locations in Tasmania but most of these places are small lakes, lagoons or waterholes and the number of birds breeding on any one of these waters is small. However, due to the large number of these breeding places and the apparent success of breeding on them, the annual cygnet production from these sources is fairly substantial. I have not estimated this figure as the task of counting the birds in the hundreds of small waterholes is beyond my resources. The main breeding grounds are at Moulting Lagoon on the East Coast, Duck River on the North-West Coast, Port Davey in the South-West. Of the three, Moulting Lagoon is the most important and was selected as the area of major study. This selection was based on grounds of accessibility as well as biological suitability. Port Davey is situated in almost uninhabited country which is difficult of access. However, it was visited by charter aircraft and the number of Black Swans there was counted. Breeding takes place on Flinders Island (off the North-East Coast of Tasmania) but this population is outside the scope of the present study though it may exercise some biological influence on the Tasmanian population. However, the number of Black Swans produced there may be large in good years and although to date there is no banding evidence to support this, it is believed that some considerable interchange of birds takes place between Flinders Island and Tasmania.

The Moulting Lagoon area (Lat. 42°S., Long. 148° 13'E.) contains two regions of brackish to salt water, namely the Swan River and Moulting Lagoon (Fig. 1). The Swan River widens on the northern side to form King Bay, an important feeding and nesting area for swans. The river then receives water from Moulting Lagoon proper and proceeds in a south-easterly direction to the sea, with Pelican Bay, another nesting and feeding ground, on the north-eastern side of the upper estuary.

Moulting Lagoon is connected by a wide entrance to the Swan River and it consists of three main bays, Watson's Bay off which to the south is Little Bay and Moulting Bay extending to the north to the Apsley Marshes through which runs the Apsley River.

The nature and usage of these waters is important in the problem of Black Swan management (Table 1). In all areas, the bottom is of thick mud with weed coverage across which it is impossible to walk or row a boat at sufficient speed to perform any useful function. In many places mud banks render any movement out of the question and the term "very shallow" refers to water of less than 4 inches depth.

TABLE 1

Moulting Lagoon waterways and their usage by Swans

Waterway	Nature	Usage by Swans
Upper Swan River	Navigable by small boat	Negligible in upper reaches
King Bay	Very shallow, unusable even by "flatties"	Very great. Feeding and resting
Lower Swan River	Navigable only in channel	Some numbers. Feeding and resting in shallows
Swan Estuary	Navigable by small boats	Nil
Pelican Bay	Shallow. Navigable only in "flatties"	Sporadic. Feeding and resting
Little Bay	Very shallow, unnavigable	Very great. Feeding and resting
Watson's Bay	Mostly navigable	Very great. Feeding and resting, with breeding on Sabinas Island
Moulting Bay	Mostly very shallow, navigable at times in channels	Very great. Feeding, nesting and breeding
Apsley Marshes	Unnavigable	Some numbers feeding, resting and breeding
Apsley River	Navigable	Some numbers feeding, resting and breeding

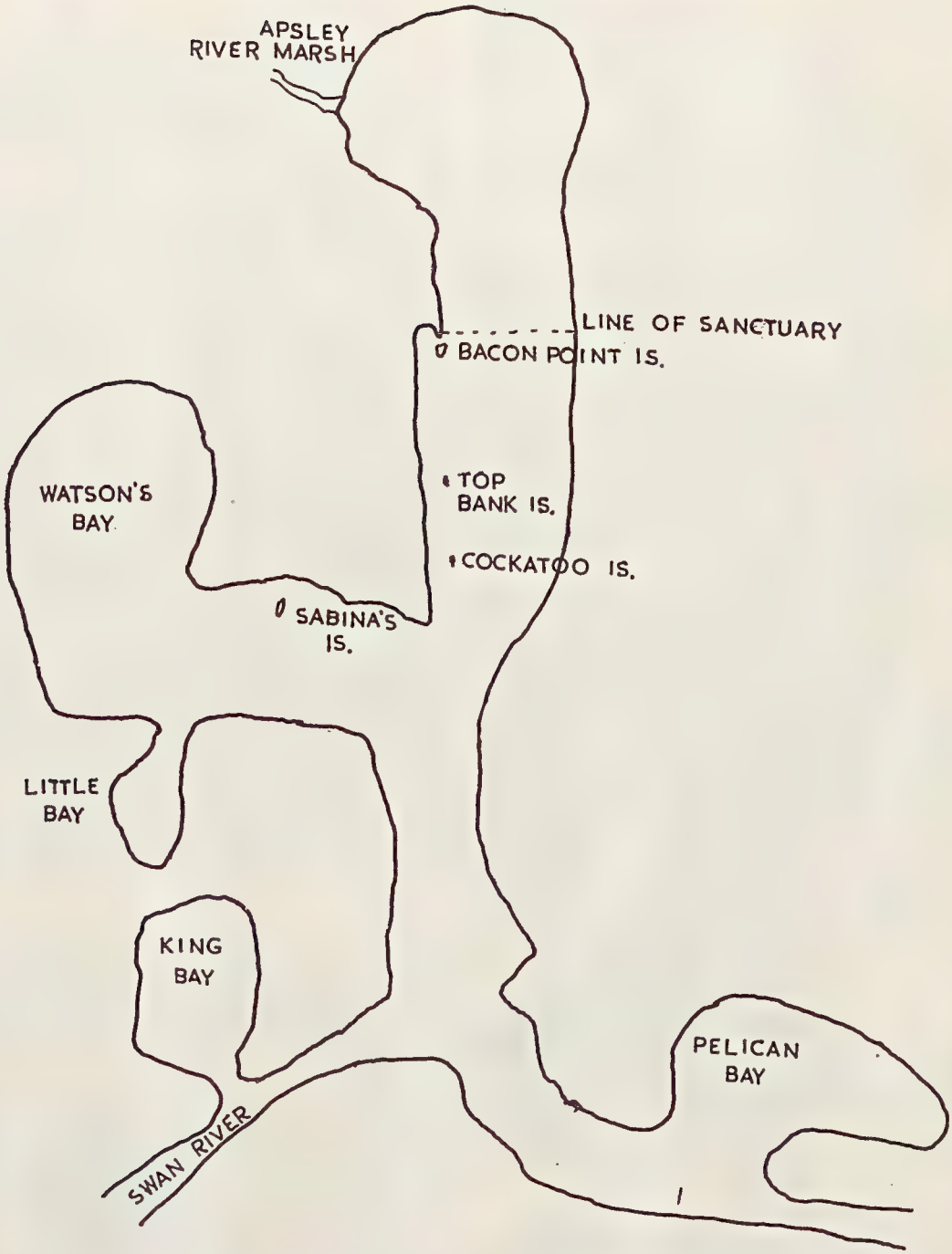

FIG. 1.—Sketch map of Moulting Lagoon, Tasmania, showing localities mentioned in the text.

From this table it is apparent that boat work must be confined to Watson's Bay and parts of Moulting Bay at those times when the water is sufficiently deep to enable an outboard motor to be used. The Apsley River can be used at all times, but it is difficult of access and only a few Black Swans can be caught there. The important populations in Little Bay, King Bay and much of Moulting Bay are quite inaccessible and can only be caught by their being driven out into navigable waters by various methods such as shooting. This method cannot be used in the northern end of Moulting Bay which is a Sanctuary.

There are 11 islands in Moulting Lagoon which are of importance. The largest of these is Sabinas Island in Watson's Bay. This island has scattered *Casuarina* trees with grassy tussocks and is used to some extent in breeding. Three other islands situated in Moulting Bay are of prime importance in breeding. These are Bacon Point Island to the north together with two tussocks adjoining it, with Top Bank Island and Cockatoo Island to the south. Bacon Point Island is of 1 acre in extent and Cockatoo and Top Bank Island are ½ and ¼ acre in extent. In addition to these, there are five islands at the southern end of Moulting Bay which are extensively used by Black Swans. These islands, with the exception of Sabinas Island, are very low lying and subject to flooding.

The shores of the lagoon are mostly low lying and either stony, muddy, sandy or vegetation covered. Only the latter are important to swans and this type of shore forms the minor portion of the edges of the lagoon. In some places there is a reed fringe of narrow extent, but this band may be as much as 100 metres in width and intercrossed by deep water channels. Such a place is from Bacon Point to the Apsley Marshes. These areas are very important for breeding. The shores of Little Bay and King Bay are composed of salt bush, *Arthrocnemon* spp. and *Salicornia* sp., neither of which are of direct importance to the breeding swans. The Apsley Marshes have a dense covering of tea tree (*Leptospermum* sp.) in very low lying swampy ground, the whole interspersed with deep-water channels. The tea tree area is important to breeding at irregular intervals. The upper parts of the marsh are devoid of tea tree but thick with rushes and a small number of pairs of swans are found breeding here.

THE NESTING SITES

1. Apsley Marshes

Nests are constructed, sometimes in large numbers, in the lower marshes and a smaller number of birds utilise the reed beds of the upper marshes for nest building. The area in the upper marsh appears to be used to some extent but they are not a major breeding area.

2. The Tea Tree

The Tea Tree area at the mouth of the Apsley River is used at irregular intervals, the birds building nests on the ground amongst the closely growing trees. Whenever the Tea Tree is used, it is utilised by large numbers of swans. It was extensively utilised in 1963 and 1964.

3. Bacon Point

This area from the Apsley Marshes to Bacon Point is formed of reeds intersected with water channels and is one of the major breeding areas. During 1960 the birds bred on an area at the north end of Bacon Point, but during 1961, 1962 and 1964 this region was used by a few birds only, the majority using an area close to the Tea Tree at the Apsley River.

4. Bacon Point Island

The island consists mainly of reeds with rushes on the eastern shore. There is some grass around the roots of the reeds.

The island was used extensively in 1960, but there were no nests built there in 1961. Few nests were used on this island in 1962 and 1963, but it had 21 nests in 1964. The adjoining mainland had a few nests built amongst the narrow reed belt in 1960 but none in 1961. The two tussocks were utilised each by one pair of birds in 1960 but none in 1961 and again by one pair in 1962.

5. Top Bank Island

The island is very low lying and is without a reed fringe, having some tussocks of grass as the principal windbreak. The absence of reeds is correlated with the rocky shoreline and the absence of mud. This island was utilised in years 1960-1964 but on account of its small size it cannot be a major breeding site, but nevertheless it is fully utilised each year (Plate I).

6. Cockatoo Island

The island is similar in topography to Top Bank Island but is higher, reaching about 70 cm. above water level. It was used extensively during the 1960-1964 seasons (Plate II).

7. Sabinas Island

This island is higher than any of the other sites, never being completely submerged. The vegetation is tussock grass (*Poa* sp.) with scattered *Casuarina* trees. Nests were built here in all the years of the survey.

8. Lagoon Nests

About 90 pairs of Black Swans build their nests in the shallow water on the mud banks and shallows of the lagoon. Most of this activity takes place in parts of Moulting Bay and the number of nests may be a significant proportion of the total, but due to flooding the breeding success frequently is very low (Plate III).

9. Islands at the South End of Moulting Bay

These are five low lying islands close to the eastern shore of the lagoon and are used regularly by breeding swans, but the islands are subject to heavy flooding. They range from 15 square yards to about 1 acre in area.

10. Southern Side of Watson's Bay

The mainland as well as a small island at the southern side of Watson's Bay is used infrequently for breeding. This island, together with (9) above, is subject to human depredations.

11. Lake Island

This is a small islet with a pond in the centre situated on the eastern shore of the lagoon.

THE NEST AND NEST BUILDING.

The first egg may be laid before the nest construction takes place though it is more usual for some start to have been made to the nest before egg laying. In the case of lagoon nests, it is obviously essential to have a nest ready for the egg. The nest is a truncated cone with a hollow cup at the top and it is constructed of various materials. The height of the nest varies considerably on the different sites depending upon availability of material. Where plenty of nesting material is on the site some nests reach 1 metre in height but 70 cm. is a common height. On the other hand, the average dimensions of 37 nests on Cockatoo Island are 14.76 cm. high, base width 94.3 cm. and cup diameter of 14.8 cm. (Plate IV).

Nest building is carried out by the female. The male collects material and brings it to the site and drops it at the edge of the nest. The female then builds it into the structure. The male may rearrange materials occasionally and may move out to the nest after the female has left. The pair have been seen to rest together on the nest.

Lagoon nests are built of the common aquatic weed of the lagoon, *Chara* sp. This is collected by the male and brought to the female who places is in position in the nest. Nest building often takes place about 1½ to 2 hours before sunset and is accompanied by displays on the part of the male. The display made by one male to the female whilst she was nest building consisted of stretching out the neck in front, partly opening the wings and fanning out the tail feathers. The male made a similar display when he climbed on the nest after the female had quitted it.

The nests on Bacon Point and on Bacon Point Island are made either of local materials, i.e., rushes and reeds or of *Chara* or of a mixture of these materials. The nests on Cockatoo Island and Top Bank Island usually are of *Chara* with whatever local material can be gathered. A chronic shortage of nesting material exists on this island.

The nests amongst the Tea Tree are made of bark, rushes, twigs, leaves and flood debris. Some of the nests in this area are well made but others may be only a few centimetres above the general land surface due to a very severe shortage of building materials. These nests are prone to flood damage, even if the water level rises but slightly.

The nest may not be completed when egg laying commences and the enlargement of the nest takes place with the eggs being kept at the surface. In all cases, whenever egg laying is finished and the nest complete, down is laid around the cup of the nest to act as a lining. The eggs are not covered with down as occurs in geese and some ducks. From time to time the lining of down may be partially renewed; and this event always takes place a few days to a week before hatching.

In the early stages of the breeding season the nesting site consists of a number of complete nests, many more incomplete and a large number of scattered eggs which may represent the beginnings of nests or be the eggs of unsuccessful breeders. Some birds lay their eggs on the ground and never build a proper nest but surround the eggs with a low (9 cm.) bank of adjoining material. This is particularly true of Cockatoo Island birds.

The nests are built at varying distances apart, the site being apparently haphazardly selected, some nests being build on the sheltered side of tussocks but others are constructed on open rocky outcrops. The distance between nests may be as close as 1 metre from the edge of one nest to the other. The average distance apart of 33 nests on Cockatoo Island is 162.5 cm. The nests in the Tea Tree are much more widely spaced, the position of the site being governed by the location of trees and creeks.

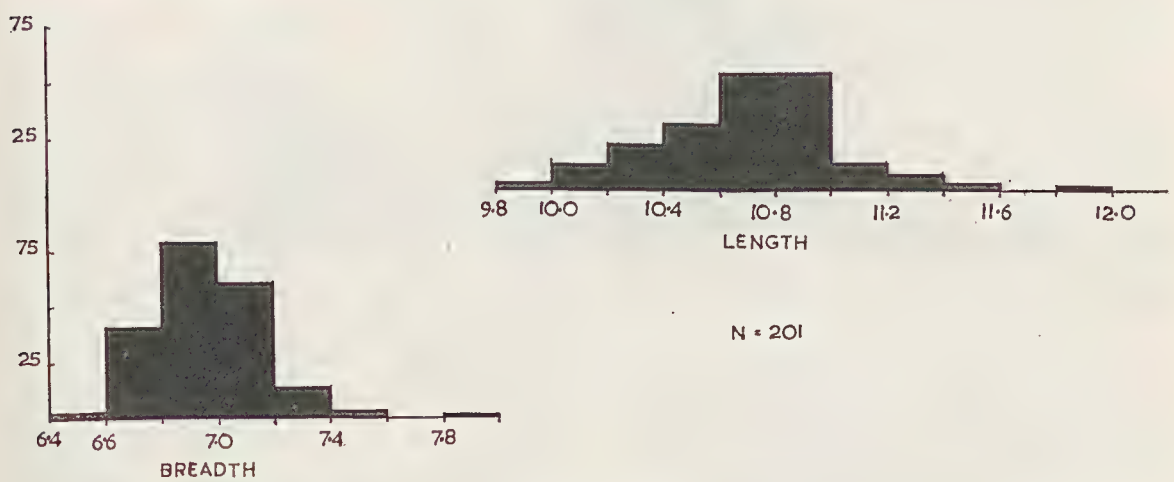

FIG. 2.—Size frequency distribution (in cms.) of eggs of the Black Swan, *Cygnis atrata*, at Moulting Lagoon, Tasmania.

Nesting sites from previous years may be refurnished and used or nests may be re-used in the same season. Material is stolen from other nests and materials from old or abandoned nests are rapidly removed for new work.

Fighting takes place between the males, often on the water. It is doubtful if this is for territorial reasons as the nests are close together but it is likely to be in defence of the mate. The offended male runs over the surface at the offender and just before reaching the opponent he draws his head back to the breast and lunges, endeavouring to catch the offender on the back. If successful he than pulls the offender under water. Generally, the offender is keen to get away from the vicinity. Face to face encounters are unusual. In these fights, the males approach each other holding their heads in a threatening position, wings half open. The birds leap up to 1 metre out of the water, pass each other, striking with the beak as they do so. This is repeated two or more times and the birds eventually settle down a few metres apart. No use is made of the wings in fighting.

The amount of fighting is negligible when the large number of birds in small areas is considered, the general impression being that the Black Swan in nature is a gentle, peaceable bird. This is sharply in contrast to introduced Mute Swans, *Cygnis olor,* on Lake Leake (Tasmania) where vicious fights take place between 18 birds living on several square miles of water.

THE EGG AND CLUTCH

The egg of *C. atrata* varies in colour from a light pale green to a duck egg blue. Freshly laid eggs are covered with a chalky white bloom which wears off the egg in the first few days after laying. The eggs soon become scratched and older eggs may show a light coppery brown hue. Some clutches remain clean but others become very dirty, even shortly after laying.

A sample of 201 eggs range in length from 9.80 cm. to 11.82 cm., with a mean of 10.69 cm. The breadth varies from 6.52 to 7.92 cm., with a mean of 6.98 cm. In 2000 eggs examined in the breeding seasons the smallest egg measured 7.70 cm. by 5.40 cm., and the largest 13.68 by 7.98 cm., with a weight of 496 g. and a volume of 383.5 cc. Sharland (pers. comm.) told me of an abnormally small egg the "size of a table tennis ball" in a nest containing normal sized eggs. The size frequency distribution is shown on Figure 2. The weight of each of 49 eggs ranged from 262.1 g. to 347.2 g., with an average weight of 299.84 g. The volume ranges from 220 to 320 cc. with a mean volume of 252 cc. This is strongly in contrast to the 700 cc. recorded by Romanoff & Romanoff (1949). The shell of the egg is thick, ranging from 0.04 to 0.09 cm. The thickness of the shell varies slightly from place to place on the same egg.

The mean dimensions of the eggs here differ from those of Delacour (1954) and Littler (1910), Delacour giving 11.5 cm. by 6.5 cm. as an average for an unstated number of eggs and Littler recording 10.8 by 6.8 for a clutch of six eggs. It is presumed that the eggs measured by Delacour were obtained from domesticated European birds and might not be representative of the species.

The egg can stand considerable compression without fracture and some flood damaged eggs were found to be sufficiently strong to support a man weighing approximately 190 lbs.

The laying of a clutch is spread over several days and depending upon the number of eggs may take up to 12 days for a clutch of six eggs to be laid. This time is unusually long, a clutch of five eggs taking six or seven days to be laid, but clutches of eight eggs are laid over a period of 10 days. some birds may lay two eggs in a 24-hour period. This may have been due to two females using the nest or to robbing or acquisition of other eggs. The mean clutch size of 579 clutches containing 2,256 eggs from all habitats except lagoon nests is 3.39. More will be said of this later. The largest clutch observed contained 11 eggs, but we have had reports of 12 eggs per clutch. These clutches may be the result of robbing (see below).

Egg laying takes place during both day and night. Observations carried out on Cockatoo Island on 19-21 August, 1962, showed that of 39 eggs laid during this period, 16 were laid between 07.00 and 17.30 hrs., i.e., during the daylight, and 23 were laid between 17.30 and 07.00 hrs.

Nest robbing by Black Swans takes place, several nests containing eggs which originally had been marked in adjoining nests or had been lying on the nearby ground. On one occasion a bird was seen to move an egg into its nest from nearby ground. Some exchange of eggs takes place during incubation.

INCUBATION

Incubation is shared by the parents (Heinroth & Heinroth, 1959) and the non-sitting partner frequently is found close to the nest. Whilst on the nest, the females remain passive but now and then stretches the neck to lunge at other nearby females who respond similarly.

Sitting commences at 42± 1 days prior to hatching so that some eggs in a clutch are incubated for up to four days longer than the most recently laid egg. Thirty-six days was the shortest incubation period noted.

HATCHING AND GROWTH OF CYGNETS.

The hatching of all the eggs of a clutch takes place over approximately 24 hours irrespective of the time of laying of the egg. During this period the first young to hatch remain on the nest pending the hatching of the remainder of the clutch upon which the mother several hours later leads the brood to water. The cygnet is very precocious and is capable of swimming strongly within a few hours of hatching, but the nest is not normally quitted until at least four hours after hatching. Generally, within 24 hours all the young have taken to the water. There is very little variation from the normal lavender grey colour of the cygnet, except the down may be slightly darker in some birds. The mean weight of 84 cygnets on hatching was 186.74 g.

Human interference with the nesting sites causes the cygnets prematurely to leave the nest and move about the site and may cause an early entry into the water. However, the cygnets swim strongly and the parents await them about 20 metres off shore and then escort them away.

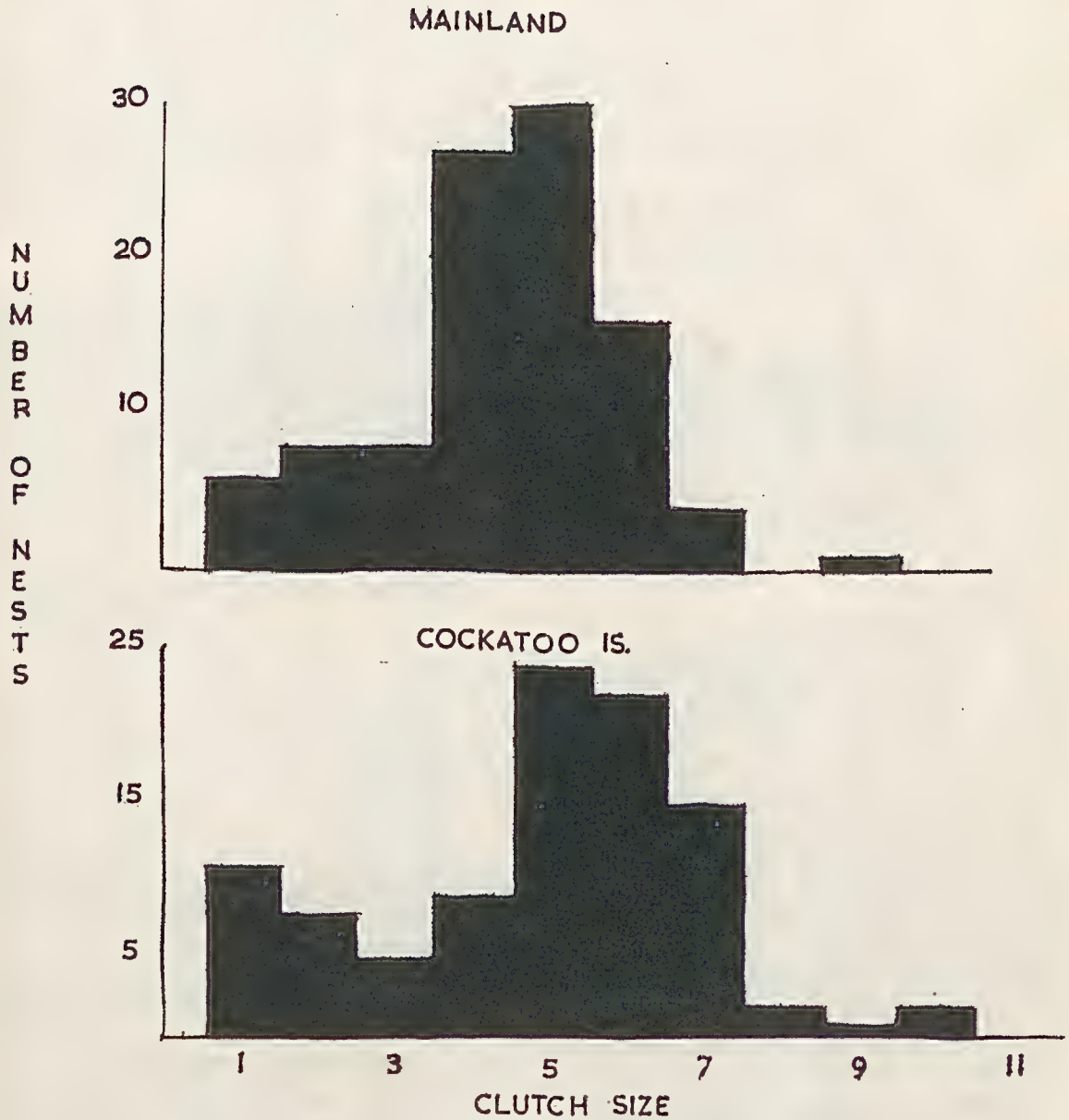

FIG. 3.—Clutch sizes of Black Swan at 520 sites in Moulting Lagoon, 1961.

The growth of juvenile plumage was noted from re-captures during banding operations. The later nestling stages have a greyish brownish tinge to the lavender grey colour of the feathers. The head is the first portion to lose the nestling feathers and this is followed in sequence by the breast, the anterior dorsal surfaces and the belly. During this, the tail becomes more distinct, but the wings are still feeble. The rump is the last part to lose the down. The beak becomes reddish purple and the eye is a light to dark brown with a black pupil. The wings and pinions develop later and the power of flight takes much longer than the development of the feathers.

The juvenile bird is lighter in colour than the adult and frequently the neck bears a few nestling feathers still adhering. The neck in young juveniles is often bicoloured, with an upper light portion separated from the lower dark part by a sharp demarcation line.

There is very great variation in the growth rate of the young bird in the wild. Forty-six cygnets captured from seven to 52 days after initial capture showed a weight gain varying from 3.0 gr./day to 44 gr./day. Seventeen cygnets gained weight at between 0-10 gr./day, 14 between 10-20 gr./day, nine between 20-30 gr./day, seven from 30-40 gr./day and two over 40 gr./day. The weights of young birds re-captured during banding show great variation in the rate of increase from the average. Some birds gain weight very slowly, others extremely quickly and any satisfactory technique to estimate the growth rate has to be designed with this variable in mind.

The time from the appearance of the first feather to the flying stage is about 60 days, though this period varies both within each brood and between broods. Flight is attained slowly, some birds requiring four months from the loss of nestling feathers to flight. One bird was incapable of flight about 11 months after hatching. Most juveniles achieve flight by about six months of age.

MOVEMENTS OF YOUNG

Immediately after the cygnets leave the nest the parents take them away from the immediate vicinity of the nesting sites. In Moulting Bay, the birds move away from the Tea Tree-Bacon Point area towards the very shallow banks on the eastern side of the lagoon, and much of the early life of the cygnet is spent there. From time to time, some cygnets and parents move out of Moulting Lagoon into Watson's Bay. Although the number of birds in Watson's Bay is not usually more than several hundred, there is a considerable turnover of individuals in the population, since banding on subsequent days yields few re-captures.

Not many swans with broods proceed further down the lagoon towards Pelican Bay. A few birds with young have been found there but the great concentration of birds is on the shallows mentioned. Within the lagoon, the birds work upwind into the sheltered localities. However, patches of very shallow water with few waves carry a large number of birds irrespective of wind direction except during gales when the weather shore is sought.

MOULT

There are always a few birds moulting at any time of the year, but in the main moult takes place after breeding during October-November. The project has not shown the proportion of the population that moults every year since relatively few adult birds have been captured as moulters and this shows that all the Black Swans in Moulting Lagoon do not moult there. Non-breeders moult during the latter part of the breeding season before the parent birds have started their moult. This moult of non-breeders may, during bad breeding seasons, be longer than the so-called main moult. The moult, when observed, is complete and the bird is unable to fly due to the loss of, or damage to flight feathers.

NUMBER OF BLACK SWANS

For reasons outlined above it is impossible to estimate the total number of Black Swans in Tasmania, but for game management purposes it is necessary to know the major fluctuations in the population. For this reason Moulting Lagoon and Port Davey were selected as areas for annual counts.

The absolute number of Black swans in Moulting Lagoon was estimated by counts on an aerial survey on 18.12.1961 when some 4000 birds were seen. This was checked by photographs and a total of 4320 birds was counted; the comparative totals are shown in Table 2.

TABLE 2

Black Swan Survey of Moulting Lagoon
11.12.61

	Count	Photograph	Averaged Total
King Bay	200	170	
Swan River	700	500	
Watson's Bay	1000	1350	
North end of Moulting Bay	1100	1200	
Moulting Bay (South end)	1000	1000	
	4000	4320	4150

Subsequent ground observations showed that the number of Black Swans in the area varied greatly from day to day and sporadic aerial surveys of this nature are of questionable value and this work was abandoned.

For comparative purposes and in order to assess the value of Port Davey as a Black Swan breeding reservoir an aerial survey of Black Swan numbers there was carried out (Table 3).

The Port Davey area did not play a major role in the breeding of Black Swans in the years 1961-64. Early reports (Lord, 1927) tell of thousands of Black Swans in Port Davey but Green and Mollison (1961) record a flock of 200 in Bathurst Harbour in 1952 and " dozens " in Hannant's Inlet in November, 1959. Clearly, assuming the early reports are correct, there has been some considerable reduction in numbers in this area since the late twenties. It also is apparent that Port Davey is a resting and feeding site but is not important in breeding.

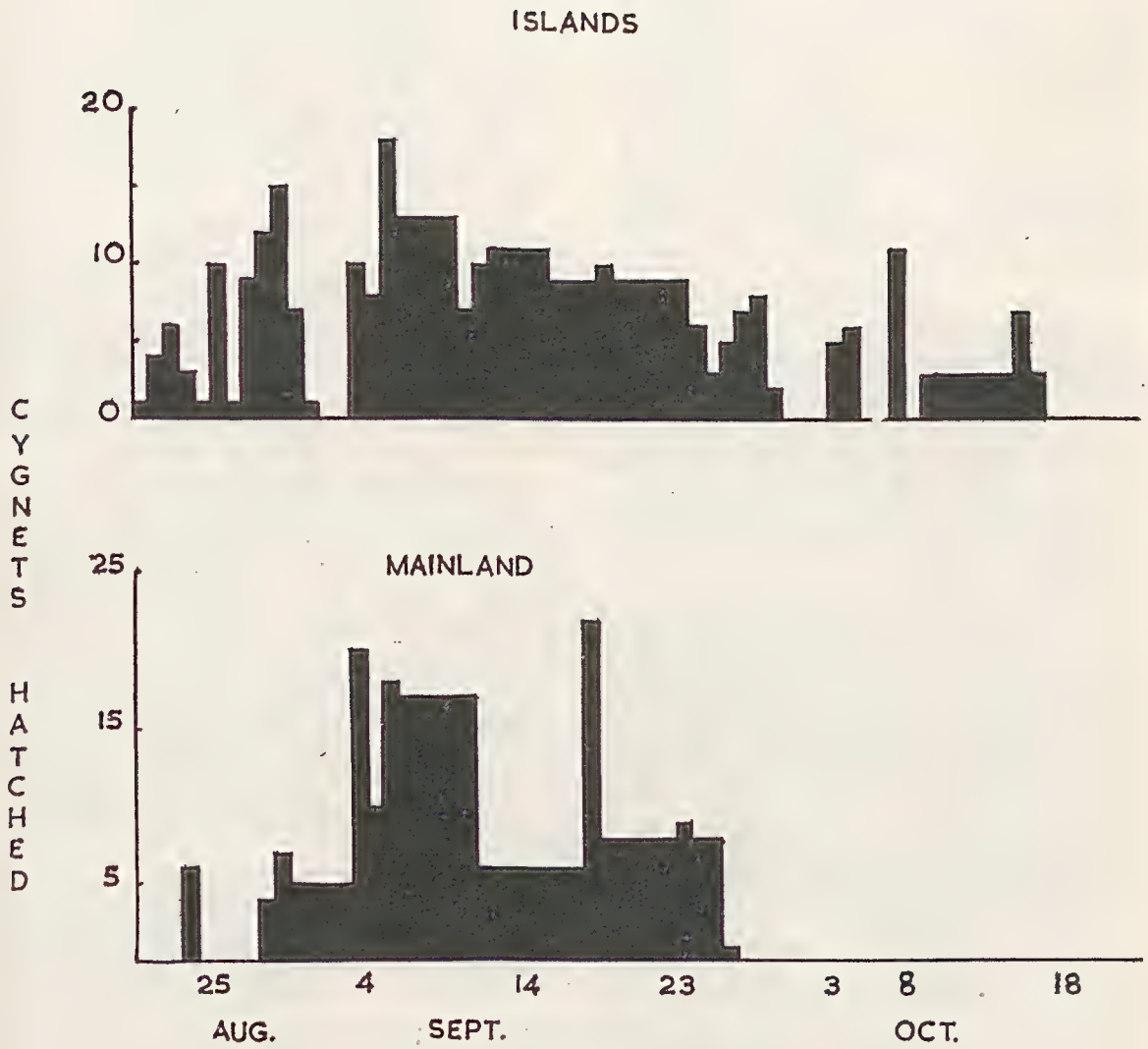

Fig. 4.—Hatching dates in 1961 for mainland and Island Black Swan breeding sites at Moulting Lagoon, Tasmania.

TABLE 3

Aerial Survey of Black Swan Numbers, Port Davey

	27.11.61			19.11.62			29.11.63	8.11.64
	Adults	Cygnets	Total	Adults	Cygnets	Total	Cygnets	Cygnets
Old River	93	6	99	42	0	42	....	....
Moulter's Lagoon	0	0	0	4	0	4	....	....
Bathurst Harbour	13	0	13	34	0	34	....	....
Celery Top I.	10	0	10	0	0	0	....	....
Swan Island	0	0	0	0	0	0	....	....
North Bay	300	6	306	383	0	383	....	....
Narrows	4	0	4	4	0	4	....	....
Joe Page's Bay	47	2	49	89	7	96	....	....
Spring River	100	11	111	0	0	0	10	....
Hannant's Inlet	332	2	334	200	0	200	....	9
Kelly Basin	310	2	312	132	7	139	....	....
Davey River	130	2	132	125	12	137	....	....
	1339	31	1390	1013	26	1039	10	9

By way of comparison the number of Black Swans on Cameron's Inlet on the eastern side of Flinders Island on 6th March, 1962, was counted from the air as over 3,000 birds. The inlet at the time was being used as a drought refuge and food was almost nil but the importance of this waterway as a refuge cannot be underestimated.

A total of 1,053 Black Swans were counted on 12th May, 1963, on the North-West Coast between Woolnorth and Smithton. This area clearly is of importance to this species.

FOOD

Swans are herbivorous but some animal protein is eaten along with the food since gastropods of several species and crustacea are common on the weeds most usually eaten. The Black Swan has no crop and the gizzard is relatively massive and crushes all food materials, rendering recognition difficult. These Black Swans must be shot during early morning feeding and the gizzard contents examined immediately.

The principal food of the Black Swan in Moulting Lagoon is *Chara* species with *Nitella* and *Ruppia* species of importance from time to time. *Salicornia* is eaten occasionally. There was no evidence of food scarcity at any time.

In areas of greater salinity, the food is mainly *Zostera* with *Cymodocea* being of secondary importance. Swans which inhabit shallow areas of salt water appear to feed almost exclusively upon *Zostera* spp.

Black Swans may feed on pasture grasses and on oats if food is scarce in the lagoon or if opportunity for terrestrial feeding is attractive.

THE 1960 BREEDING SEASON

The main breeding in Moulting Lagoon in 1960 took place on Bacon Point, Bacon Point Island, Top Bank Island and Cockatoo Island. Observations were made mainly on Bacon Point Island with subsidiary observations on the other three localities. About 30 nests were constructed and used on Sabinas Island but these were not visited by the author. In addition, a number of nests were constructed in the shallows of the lagoon.

The brief history of the 1960 season was that hundreds of eggs were noted washed out of nests by floods on 18th July and the surviving eggs were hatching on 2nd August. A further laying took place in August and this too was washed out by floods. More eggs were laid in November and December and a successful hatch appeared from this late laying.

GONAD DEVELOPMENT

Regular samples of six birds each were shot in Watson's Bay and Little Bay. The gonads were measured then fixed in Bouin's Fluid. The development of the gonads, based upon testis volume and oocyte size is shown in Table 4.

TABLE 4

Gonad sizes of 38 samples of Black Swans from King Bay, Moulting Lagoon. Testis volume in cc. and oocyte sizes in cm.

	Male			Female		
Date	No.	Total vol. of both testes	Av. vol.	No.	Vol.	Oocyte size
2.5.60	2	2.30	1.10	4	4.10	0.38
24.5.60	4	6.20	3.15	2	3.50	0.60
25.7.60	3	31.60	9.62	4	8.20	1.03
16.8.60	2	10.00	6.88	3	7.00	0.67
23.8.60	—	—	—	6	26.8	1.13
26.9.60	2	23.00	11.5	6	5.00	0.71

In determining these measurements, the six largest oocytes in each ovary were measured and each sample was averaged on individual mean measurements.

These figures show the development of the gonad but only in one case was a larger egg (5.35 mm.) found in the gonad and the testis in no instance showed a mature condition. The evidence shows that the population sampled in King Bay was in the pre-breeding stages of gonad maturation. At the same time birds were actively mating and laying on the breeding sites. Thus, final stages of maturation take place in the breeding area and there is very little, if any, movement of the population out of the area during the breeding phase.

In general, the right testis is larger than the left but the reverse holds true in many Black Swans.

THE FIRST LAYING

The first visit to the lagoon was on 2.8.1960 when a clutch of five was observed hatching. From later knowledge, this clutch must have been laid between 28th June and 16th July. Local residents state that this laying date was abnormally early, and late July and August is the more normal time. This was the only surviving clutch of the June laying which hatched. The known mortalities are shown in Table 5.

TABLE 5

Number of eggs destroyed by floods in Moulting Lagoon and found on 2.7.1960.

Area	No. of eggs
Cockatoo Island	336
Top Bank Island	102
Bacon Point Island	40
	478

This figure represents the minimum and does not include the large number of eggs washed off the nesting sites which could be seen lying on the bottom of the lagoon.

Egg-laying had re-commenced on 2nd August and 30 nests on Bacon Point Island were in use.

Some of these eggs hatched but the great majority were washed away in a flood on 16th-18th September.

Sporadic breeding by a few pairs took place in October and November, but this was overshadowed by a major egg-laying near the entrance to the Apsley River which took place towards the end of December. These eggs hatched in early February and by 25th February there were a large number of small cygnets in the lagoon.

The details of the August breeding were examined on Bacon Point Island by visits at irregular intervals and Table 6 summarises the results.

TABLE 6

Details of Bacon Point Island Hatching, August, 1960.

No. of nests	109	No. of eggs	494
No. of nests used twice	7	No. of eggs	17
	116		511

Clutches hatched 100%	7
Clutches hatched less than 100%	109
No. of cygnets hatched	61
(or possibly	67)

Reasons for failure of egg to hatch:

1. Addled	6
2. Predated	39
3. Bad mother	24
4. Robbed *ex* another nest	1
5. Broken	0
6. Fallen from nest	5
7. Nest abandoned	25
8. Robbed by another swan	0
9. Incomplete hatching	0
10. Dead cygnet in egg	0
11. Flooded nest	348
12. Eggs buried in nest	0
13. Post natal cygnet death	0
	448

In the above table some of the reasons for egg failures are self-explanatory but others require some elucidation. A bad mother refers to the bird that lays an egg or eggs but makes no attempt to nest build or to incubate the eggs. This is different from the case where a nest is constructed and eggs laid but subsequently abandoned after some incubation (7). There were no eggs noted during the observation period that could be described as infertile, all the addled eggs examined had undergone some development and there was no evidence of infertility.

It is quite clear that the greatest mortality of eggs was due to floods and any other mortalities were of a secondary nature, with predation, nest abandonment and bad mother being the main causes of failure to hatch. Of these, predation may have been unduly high on account of the number of nests which were flood damaged and eggs subsequently predated. Care was taken to ensure that eggs noted as predated were taken from nests containing warm eggs, i.e., used nests, but some error may have occurred. Predation may have been heavier than normal due to our presence on the area allowing the predators better facilities, but flood damaged or abandoned eggs were attacked more frequently than fresh warm eggs.

THE 1961 BREEDING SEASON

The sites used this year contrasted with ones used in 1960. Of last year's breeding sites, only Cockatoo Island and Top Bank Island were used by numbers of birds. Nests also were constructed in the shallows of the lagoon as in 1960. However, the greatest nesting activity was on a stretch of swampy ground, much intersected with narrow water channels situated about 150 yards to the south of the opening of the Apsley River.

Egg-laying commenced on or about 12th July and the first cygnets hatched on 20th August. Greatest laying activity took place in the first two weeks of August. The number of eggs laid on the various sites is given in Table 7.

Egg-laying took place sporadically after the main laying and the latest eggs laid in the study areas were on 16th October on Cockatoo Island. However, it is known that swans have an attenuated breeding season and from the size of one clutch of cygnets banded in February, there must have been some late laying in November. Littler (1910) gives the breeding season as August to December generally, January sometimes.

The number of eggs laid in 1961 is shown in Table 7.

TABLE 7

Number of Black Swan eggs laid at breeding sites in Moulting Lagoon, 1961. The figure in brackets is an estimated total based on the mean clutch size.

Area	First Usage of nest	Second	Third	Total	Total sites	Mean clutch size
Cockatoo Is.	539	155	2	696	152	4.578
Top Bank Is.	100	0	0	105	—	—
Bacon Point	115	5	2	536	122	4.400
"Lagoon"	0	0	0	(362)	93	—

The distribution of clutch sizes is shown in Fig. 3. The mainland clutch sizes follow a normal distribution but those of the islands depart significantly from the normal at more than 1% level. The mean clutch sizes do not differ significantly on a test but a variance ratio test shows a significant difference at the 0.1% level. Thus, the two populations laying on the mainland and Cockatoo Island statistically are significantly different. This difference may be attributed to young females breeding for the first time and laying on the island as being the most convenient place, and also to a preference for the presumably safer and terrestrial predator-free islands.

The hatching data and breeding success are shown in Tables 8 and 9.

TABLE 8

Hatching data for Bacon Point and Cockatoo Island (in italic type) for the 1961 breeding season.

No. of nests	110	*109*	Eggs laid	494	*513*
No. of nests used twice	10	*43*	Eggs laid	37	*181*
No. of nests used thrice	4	*6*	Eggs laid	5	*2*
Total	124	*158*		536	*696*
Clutches hatched 100%	58	*43*			
Less than 100%	53	*72*	No. of cygnets hatched	316	*419*
Reasons for failure of eggs to hatch:					
1. Addled	17	*21*	9. Incomplete hatching	0	*1*
2. Predated	53	*43*	10. Dead cygnet in egg	1	*1*
3. Bad mother	19	*25*	11. Flooded nest	31	*2*
4. Robbed *ex* another	0	*3*	12. Egg buried in nest	0	*5*
5. Broken	0	*2*	13. Post natal cygnet death	1	*2*
6. Fallen from nest	1	*2*			
7. Nest abandoned	51	*48*		174	*150*
8. Robbed by another bird	0	*7*			

The peak of egg-laying occurred during the first week of August but substantial numbers were being laid in the observed 112 nests at Bacon Point in 16th August (34 eggs). However, the number being laid fell rapidly after that date with the second laying appearing on 5/9 and extending to 23/9. The peak of hatching occurred in early September, but was more attenuated on the islands than on the mainland (Fig. 4).

TABLE 9

Breeding success of Black Swans in Moulting Lagoon—1961.

Total number of nests	715
Mean clutch	4.489
Potential hatch	3209
Percentage hatch	63%
Actual hatch	2021 cygnets (429 broods)
Less immediate post-natal deaths	8
Production	2013 cygnets
Mead brood size of 102 broods	3.70
Mean brood size at hatch	4.82
Mortality	1.12/brood
Net production	2013 less 480 = 1530 cygnets

THE 1962 BREEDING SEASON

During this season the breeding sites used were more widespread and more birds participated in the breeding than in either of the previous years. All of the sites were again used but in addition, a number of sites hitherto unutilised during the present survey had nests on them and some birds returned to Bacon Point Island (Table 10).

TABLE 10

Sites used in the 1962 breeding season at Moulting Lagoon, together with the number of eggs laid.

Location	Nests	Eggs	Mean clutch
Cockatoo Is.	100	579	5.790
Top Bank Is.	26	112	4.308
Bacon Point Is.	4	23	5.600
Bacon Point	43	194	4,512
South side of Watson's Bay	56	Eggs stolen	—
Island near above	10	47	4.700
Sabinas Is.	47	232	4.936
South Is.—			
No. 1	119	607	5.100
No. 2	61	303	4.970
No. 3	37	193	5.210
No. 4	18	95	5.270
No. 5	52	258	4.960
Tea Tree	454	1861	4.101
	1021	4504	4.410

The first nests were noted on 2nd August and the first eggs were found on Top Bank Island and Cockatoo Island on 6th August. This was later than in previous years and the birds were slower in reaching the peak of egg-laying (Fig. 5) which did not occur until 19th-20th August.

The weather apparently was suited to swan breeding and no flooding took place. The main cause of mortality was abandonment of the nests with predation being the next most important factor (Table 11).

TABLE 11

Hatching data for Black Swans at two sites in Moulting Lagoon in 1962.

	Mainland	Cockatoo Is.
No. of nests	42	89
No. of sites used twice	0	11
Total No. of eggs	190	464
Clutches hatched 100%	21	45
Clutches hatched less than 100%	21	33
No. of cygnets	131	342
Reasons for failure to hatch:		
Addled	5 = 2.6%	12 = 2.6%
Predated	13 = 6.8%	17 = 3.7%
Bad mother	3 = 1.8%	15 = 3.2%
Robbed *ex* another	0	0
Broken	0	1 = 0.2%
Fallen from nest	0	0
Nest abandoned	33 = 17.4%	57 = 12.7%
Robbed by another bird	0	0
Incomplete hatching	0	0
Dead cygnet in egg	0	0
Flooded nest	4 = 2.7%	0
Egg buried in nest	0	0
Post natal cygnet death	0	0
	58	102

TABLE 12

Breeding success of Black Swans in Moulting Lagoon in 1962.

Total No. of nests	1021	
Mean clutch size	4.410	
Potential hatch	4504	
Percentage hatch	71.826	
Actual hatch (estimated)	3235 734	(broods)
Less immediate post natal deaths (estimated)	25	
Production of cygnets	3210	
Mean brood size at hatching	5.344	
Mean brood size	4.454	
Brood mortality	0.890	
Brood casualties	553	
Net production	2657	

COMPARISON OF 1960-1964 BREEDING SEASONS

The breeding data for the various localities is set out in Table 13.

TABLE 13

Black Swan breeding date for sites in Moulting Lagoon, 1960-1964. *The Lake Is. site was not discovered until* 1964.

	1960	1961	1962	1963	1964
Watson's Bay Is.	....	....	56 nests	....	....
Sabinas Is.	110 est.	....	232	686	3034
Southern Is.	....	....	287	834	1128
Cockatoo Is.	....	....	579	622	515
Top Bank Is.	....	....	112	136	161
Bacon Pt. Is.	....	....	23	52	216
Bacon Point	....	....	194	747	2370
Tea Tree	....	....	1861	1391	784
Apsley Marshes	....	....	(in above)	....	113
Lagoon nests	....	....	....	94	612
Lake Is.	....	....	....	....	101
	....	....	1021	4562	9034

The location of the main breeding effort alters each year but the Tea Tree, Bacon Point, the Southern Islands and, possibly, Sabinas Is. always being important. The reason for this change of site is not known.

THE BROOD

Few cygnets die on the nesting area but a mortarity occurs after the young birds leave the nest. The mean size of 100 broods on hatching in 1962 was 4.82 whereas the mean of 100 broods counted from the air was 3.48 and of 62 captured during the banding operations the mean was 3.93 (average of these last two being 3.7), showing that there was a mortality rate of 1.12 birds per brood.

Interference with the brood does not affect their acceptability to the mother nor does the scattering of the brood due to banding activities prevent the parents from collecting them together, since broods were re-captured intact a day after their original capture. However, in the later stages of the pre-flight period a large number of young were taken which apparently were living separate from either parents or the rest of the brood. This is not the result of banding operations but due to a greater independence of the young at later pre-flight stages and to the breaking up of the brood as some achieve flight.

PREDATORS

The adult Black Swan has not been observed to be attacked by any other birds and must be regarded as free from predators. The main predation takes place during the egg stage and also during the early pre-flight life of the cygnet.

The predation on the eggs is mainly carried out by the Australian Raven, *Corvus coronoides* (Gould), large numbers of this species being seen around the nesting sites. The ravens take eggs from abandoned nests or those dropped by "bad mothers" and the predation from actively used nests is not great. The Swamp Harrier, *Circus approximans* (Forster) is a similar predator. The importance of lambing in adjacent properties in relation to Black Swan breeding should not be overlooked. Large numbers of Ravens are attracted to either the lambing or swan nesting, depending upon which takes place first. In 1960 there were few Ravens at the islands but large numbers in the lambing paddocks whereas in 1961 the reverse held true.

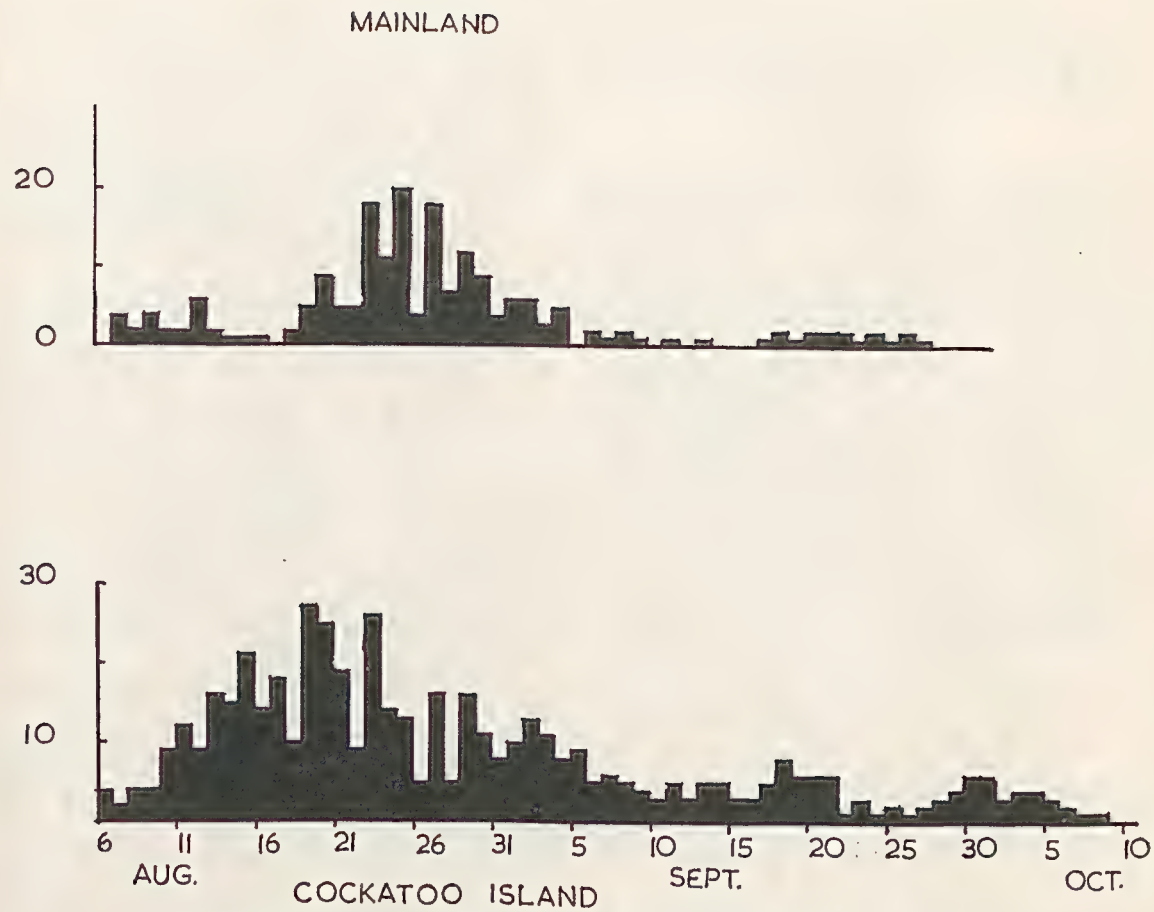

FIG. 5.—Black Swan egg-laying on Cockatoo Island and mainland, Moulting Lagoon, 1962.

Other lesser predators on eggs are the Rat, *Rattus norvegicus* and the Yellow-bellied Swamp Rat, *Hydromys chrysogaster* (Geoffrey). These is no doubt that the Native Cat, *Dasyurus quoll* (Geoffrey) would take eggs given the opportunity but no *Dasyurus* were observed in the nesting area. Frequent pads of the Tasmanian Devil, *Sarcophilus harrisii* (Boitard) occur in the area and these animals undoubtedly would devour such eggs and cygnets as were presented to them. The cygnets usually swim beside the parents but rarely the young are carried on the back of the parent bird. The cygnet is thus liable to predation by hawks should it stray too far from the parent birds. The young cygnet is the prey for the Sea Eagle, *Haliaetus leucogaster* Gmelin. This species has been seen to remove eggs from the nests and one individual was seen to take a live cygnet from Cockatoo Island. The arrival of a Sea Eagle causes great turmoil amongst the adult Swans. Swamp Harriers, Gulls and Terns also kill cygnets, the latter only doing so whilst the cygnets are on the water.

A parasitological and pathological examination was carried out in the laboratory on all swans shot. The only parasite found was *Drepanidotaenia bisacculina*. This is remarkable in that no less than 16 species of Cestode are recorded by Lapage (1961) from the Black Swan together with 19 other endoparasites. The restricted area from which the specimens were collected may be important in this regard and may explain the absence of other species, though banding returns show that individuals may travel very widely.

The number of *Drepanidotaenia* in each Black Swan was counted and the infestations ranged from zero to 500. There was no correlation between the number of worms and the condition of the host, the bird with the heaviest infestation being in "poor" condition, while one with only 50 fewer parasites was described as "very fat". Other birds with no parasites were in 'poor' condition.

The worms varied greatly in size but all the segments in different individuals had reached the same sexual maturity. The same feature was noted by Southwell and Kirshner (1937).

The pathological examination revealed that some birds showed fatty degeneration of the liver and one bird had cirrosis of the liver together with areas of necrosis. In this same bird, the spleen was enlarged with areas of fibrosis and bad scars.

BANDING

A small number (128) of Black Swans were banded at Moulting Lagoon in 1960 and these were ringed with C.S.I.R.O. bands. Further banding work has been carried out and by July, 1965, 4,315 Swans have been banded. The emphasis of banding has been placed upon birds of the year, although moulters have been taken as the opportunity presented itself. The data collected were used for statistical estimations of the cygnet production in 1962 and 1963 using both positive and negative regressions. From this calculation, the number of cygnets at the commencement of the banding was 2,200 and that estimated at the conclusion of the banding was 1,250 (Table 14). The populations estimated from the banding operations differ but slightly from those in Table 9, especially in the estimates made at the commencement of banding.

TABLE 14

Trellis diagram for regression calculation of population of cygnets of Black Swans, Moulting Lagoon, 1962.

		t_2	t_3	t_4	t_5
t_1	65	0	11	8	4
t_2		97	12	13	5
t_3			67	12	1
t_4				106	7
					70

In table 14 the data are grouped into 5 lots, namely t_1—28th Nov. to 1st Dec., 1961, t_2—12th Dec. to 13th Dec., 1961 t_3—9th Jan. 1962 to 10th Jan., 1962, t_4—6th Feb. to 7th Feb., 1962 and t_5—23rd Feb., 1964. The time intervals separating these lots are thus 11, 26, 26 and 16 days respectively. The figures within the trellis represented the number of each group re-captured at the date of operations. The sample was standardised to 100, then

$$r+ = \frac{y^2 + y^3 + y^4 \ldots yn^{-1}}{y^1 + y^2 + y^3 \ldots yn}$$

where y^2 = No. of t_1 birds re-captured on occasion 3

$$\text{and } a_o = \frac{y^1 + y^2 + y^3 + y^4 \ldots yn^{-1}}{r+}$$

$$N^t1 = \frac{10.000}{a_o}$$

The estimated production of cygnets in 1963 also was calculated from the re-capture data (Table 15). It will be seen from these estimates that the population varied from 6,702 to 576 and only on three occasions, namely 11th January, 9th and 22nd February, did the estimated population agree with that found by direct observation, the mean of the estimated populations on these dates being 2,759. If the data are statistically standardised the error in the estimation becomes greater. However, it is to be expected that the number of cygnets will fall during banding operations as further birds become capable of flight.

The difference between the statistically estimated population of cygnets and that gained by direct observation primarily is due to non-random sampling of population which in turn is attributed to the nature of the waterways (Table 1). This error is increased by the changes in wind direction which cause unpredictable movements in the bird flocks. Human activities in the area including the banding operations, further accentuate the non-random nature of the sample. The behaviour of the young also increases the statistical error since mixing the population apparently does not occur constantly and all samples taken later in the year are affected, flying young, leaving the population. It is apparent that the close correlation between known cygnet production and that estimated from re-capture data in 1961 was fortuitous and could have been misleading.

Recoveries of dead banded birds show that about 3% of the cygnet crop dies before achieving flight. This figure is very low.

The returns from shooters have shown that birds banded at Moulting Lagoon have been shot on the North-East Coast of Tasmania as well as on lakes in the Central Highlands. The absence of band returns from the North-West, South and West merely reflects the small amount of shooting in those areas. It can be deduced that some of the Black Swan population moves about this State, which is in contrast to earlier belief (Sharland, 1958). However, the frequency of re-trapping of some individual Black Swans at Moulting Lagoon leads to the conclusion that some birds are fairly static in habits and in the case of one bird it appears likely that it is incapable of flight, having been caught without pinions on four occasions in 12 months.

One banded Black Swan was returned from Flinders Island and two from New South Wales (Corowa and Cowra respectively). No bands have been recovered from Victoria. The extent of the movement of Black Swans to the Mainland of Australia is not known.

MANAGEMENT PROBLEMS

The problems which are of concern to Tasmania are associated with keeping the Black Swan population up to a reasonable level, rather than controlling the numbers. This is in contrast to the situation in Victoria where the Swan population has to be controlled to minimise pasture damage. The New Zealand Black Swans, which are an exotic species, are controlled only in areas of large numbers. Pasture damage occurs sporadically in Tasmania and is only local in nature and is controlled by the issuing of special permits to destroy or frighten the offending birds.

TABLE 15

Trellis diagram for Moulting Lagoon, 1963, based upon re-captures of 1962-bred Cygnets.

Date	8/1	11/1	22/1	2/2	9/2	22/2	15/3	30/4	9/5	16/5	23/5	30/5	6/6	21/6	2/7
Pop. Size	6702	2751	1433	1395	2679	2839	998	1042	1840	920	576	956	—	—	—

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}	t_{13}	t_{14}	t_{15}	ΣR
t_2	90	2	2	8	10	6	7	9	9	5	6	10	4	3	2	13
1207	33	1	2	13	14	1	4	3	11	4	6	7	3	1	69	2
1117	47	5	0	3	6	6	4	6	4	1	6	9	2	59	4
1084	115	0	3	1	6	0	11	7	6	2	8	1	61	9
1037	76	2	0	1	4	2	7	5	5	2	1	77	27
922	246	0	2	0	6	2	5	4	1	0	89	27
846	74	1	0	4	5	1	8	5	1	70	14
600	88	0	2	1	4	1	6	0	88	37
526	70	1	0	1	8	4	0	74	39
438	89	0	0	2	3	1	246	52
368	77	2	1	0	0	76	24
279	61	1	1	0	115	66
202	59	0	0	47	34
141	69	0	33	13
13	13	90	15

TOTAL BIRDS CAPTURED

CAPTURES

RELEASES

$$N = \Sigma T \frac{N}{\Sigma R}$$

(a) OPEN SEASONS

The Black Swan was the subject of open seasons for many years but from about 1923 until 1958 there were no open seasons. The recent open seasons are given in Table 16.

TABLE 16

List and duration of open season on Black Swan in Tasmania, together with licences issued and bag limits. The kill is estimated allowing each hunter half a bag limit per one day only. This method of kill estimation is based on the fact that most shooting takes place on opening day and on the observations of inspectors when inspecting bags and it is probably an underestimation.

Year	Licences	Duration	Bag Limit	Estimated Kill	Breeding
1958	330	11 days	6/day	990	Poor
1959	1384	8 days	4/day	2768	Very poor
1960	....	closed	....	....	Fair
1961	1406	3 days	6/day	4218	Poor
1962	....	closed	....	....	Good
1963	527	3 days	6/day	266 (400)	Good
1964	836	9 days	4/day	800	Good
				9042	

Most of Moulting Bay was closed in the 1963 season and the number of birds killed (266) is an accurate count based upon bag checks and the figure of 400 is the estimated total for the whole of the State.

The re-opening of seasons, with large kills in 1958 and 1959 resulted in a reduction in the number of Swans in the Moulting Lagoon area and initiated the present investigation. The estimated kill of 2,768 in 1959 followed by the large kill of 4,218 in 1961 resuted in the closure of the season since the latter figure was greatly in excess of the estimated production of 1,530 young Black Swans for that year.

Concern was felt that the Black Swan season occurred at a time when pairing of the adults had taken place and also that most of the shooting took place over the breeding areas of the Swans. It was decided in 1963 to open the season only for areas of relative unimportance to Black Swan breeding, i.e., all of Moulting Bay was closed. In addition, the season was shortened. These measures had the result of bringing the kill down to well below the estimated production for 1963. The same policy was followed in 1964. The significant result of these measures was that the breeding success of the Black Swans increased greatly from 2,657 in 1962 to 3,650 and 7,250 in 1963 and 1964. It is clear that the shooting over the breeding areas is not a desirable feature and should not be permitted.

The apparent success of the restriction of shooting over the breeding grounds led to a more positive approach to the shooting and the season was lengthened in 1964 to enable shooters to take a larger proportion of the crop. In future years the survey of the breeding success should be continued and used as a basis for determining the duration and bag limit of any future season.

During the examination of specimens in 1960 one pellet was found encapsuled in the gizzard and during banding operations two birds were found with broken wings which could have been the result of gunshot wounds. These birds were in good condition.

The shooting pressure upon the Black Swans was assessed during band returns from shooters as an index. The returns of bands from Swans shot in an open season can be used to indicate the shooting pressure upon the species (Table 17.) The samples are too small at present for valid comparisons and the shooting pressures will be the topic of a future contribution.

The rate of exploitation of each year group is low, 1961 being the only year in which the number of bands reached 10%, though it must be remembered that the total number of banded Black Swans was low. The Black Swan population can stand exploitation at this level and as long as the annual kill does not exceed the production there should be no difficulty in maintaining the numbers.

The percentage return of bands from each year is remarkably constant, with the exception of the initial small number of bands in 1960. It is apparent that the population is being shot indiscriminately and over a period there is not a large percentage of any year group being killed.

(b) BREEDING

It has been shown that the Black Swan breeds during the austral winter and thus the nests are prone to the effects of flooding during the winter rains.

The three breeding seasons, 1960-64, are sharply different in the effect of this factor on the success of breeding of the Black Swan. The major cause of the failure of breeding in 1960 was flooding which was responsible for the destruction of 68% of the eggs laid during the early laying. Flooding was responsible for only 5.8% of the egg mortality in one locality in 1962, and a negligible number of nests suffered from this cause in 1963, though early eggs in 1964 were washed off the Lagoon nests and the South islands (Fig. 6).

TABLE 17

Return of bands from Black Swan shooters in Tasmania.

Banding Year	Number	Recoveries in years following banding 1960	1961	1962	1963	1964	Total Recoveries	
1960	128							
1961	....	24					24	10.9%
1962	735		CLOSED SEASON					
1963	946	0	7	9			16	1.7%
1964	1000	1	13	13	11		37	3.7%
1965	1634	0	10	18	25	72	125	7.06%
Totals	4315	25	30	40	36	72	202	4.6%
Bands recovered		11.7%	4.08%	4.2%	3.6%	4.4%		

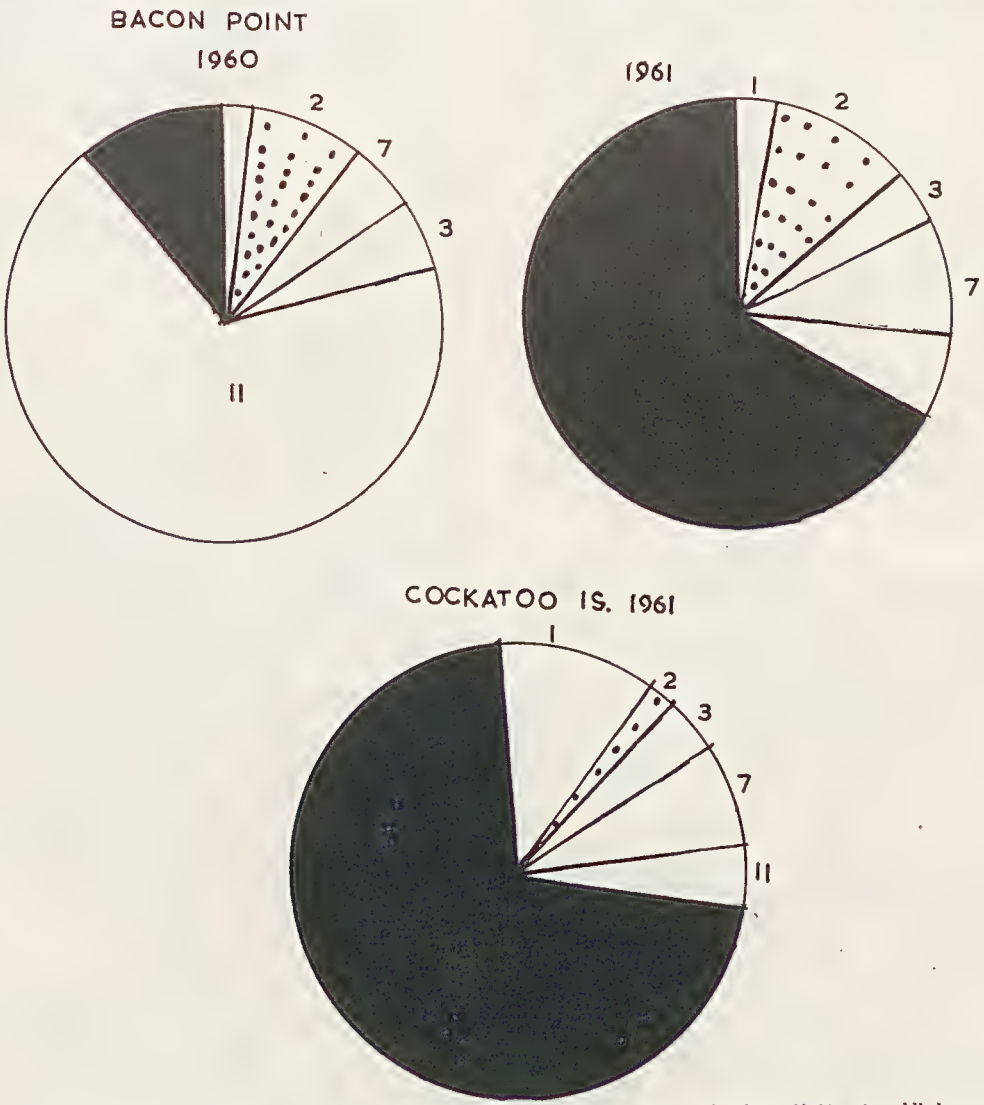

FIG. 6.—Causes of Black Swan egg mortality, Moulting Lagoon, Tasmania, in 1960-61. 1—addled eggs; 2—predated; 3—bad mother; 7—abandoned; 11—flooded; black—successfully hatched.

The floods result from precipitation in the extensive watersheds of the Apsley River combined with south to south-westerly winds and high tides, both coincident with wet weather, which back up the seas at the restricted entrance to the Lagoon. A tide gauge was maintained in the lower Apsley Marshes from 3.5.61-16.10.61 and the normal level of the river was about 9″ Recorder Datum (R.D.). The maximum height reached by the water was 6′ 4″ R.D. and 5′ 0″ R.D. was exceeded twice. The rise in level may be rapid, a rise of 3′ 3″ being recorded in 23 hours and small rises of more than 3″ per hour were frequent. This latter was associated with the maximum flood of 6′ 4″. It must be stressed that the winter of 1961 was abnormally dry and these floods were very low and only a small percentage of the eggs were affected. Whenever major flooding occurs the whole nesting area is inundated as in 1960, these floods being estimated to be at about 8′ 0″ R.D. It is clearly impossible to control these floods and other methods of nest protection have to be used. The raising of the general level of the nesting sites presents difficulties in the mechanical handling of large quantities of materials over muddy shallow water and the most satisfactory method is in the provision of floating nesting sites.

The general pattern of breeding shows that Swans commence egg-laying earlier on the islands and the clutch size laid there is larger than on the mainland. This indicates a preference for islands as breeding sites and the birds even build their nests on the low-lying swamps, this reflecting the shortages of island nesting sites. The provision of suitable floating nest sites, such as rafts, motor tyre tubes, fulfils the apparent preference for island habitats and also is necessary to overcome the flood problem. However, in view of the ability of Black Swans to breed again after floods, it is doubtful if such measures would serve any useful purpose.

(c) GENERAL

The Black Swan is a heavy bird, adults averaging 15 lbs. in weight and the effort of climbing on to an island is accompanied by much scratching with the feet. This causes a reduction in the shoreline of islands and over a period of twenty years Top Bank Island has been reduced to about one-third of its original area. This process has taken place on other islands and the destruction of habitat has reduced the area available for breeding. The placing of stones around the edges of the islands can arrest this erosion.

Some degree of egg-management is currently being practised. There are always a number of eggs lying on the surface of the islands and these are not incorporated in nests and furnish a source of food for scavenging predators such as water rats and crows. These eggs if placed in nests of low clutch size are acceptable to the brooding bird and an increase in the effective clutch size can be obtained by this method. Only one egg is placed in each nest and each egg has to be placed in a clutch which has not commenced incubation. Disturbance of the nest causes little upset to the breeding birds and does not cause undue nest abandonment. Undoubtedly some nests were abandoned as a result of our activities in 1960-61 but the 1963 season, when the examination of the nests were less frequent, saw few nests abandoned by the birds. The Black Swan is not an easy species in which to inhibit breeding and any breeding disasters within the normal breeding season are countered by a subsequent egg-laying.

The relation between open seasons and the subsequent efficiency of breeding has occupied much effort. The shooting season takes place in April, this month being considered suitable because the young birds of the year are able to fly by that time and there are no nests being constructed for breeding. The gonad examination showed that development of the gonad may commence in February and pair formation takes place in March-April, but nest building does not commence until July. The period of the open season thus interferes with pair formation and may break established pairs. The traditional main hunting areas are King and Little Bays in the southern part of the Lagoon and Moulting Bay, the northern end of which is a Sanctuary where hunting is forbidden. These hunting grounds, particularly in Moulting Bay, coincide with much of the breeding area of the birds and consequently the April season not only disrupts pair formation but the shooting and disturbance takes place over the breeding sites. After the 1958, 1959 and 1961 open seasons, the breeding was poor, but in 1960 and 1962 when there was no shooting, the breeding was fair to good (Table 16). This was believed to be due to the effects of the shooting. It was decided in 1963 to hold a short open season but as an experiment to close Moulting Bay, Little Bay and Watson's Bay to shooting so that the paired birds would be protected and only the non-breeders and a minimum number of breeders would be liable to shooting. The 1964 restricted season was followed by the best breeding observed to date and, following similar restrictions in 1964, even better breeding results were obtained. The climatic factors associated with the 1963 season did not fulfil the conditions one might expect for good breeding, being abnormally dry with low rainfall, and local residents agree with this conclusion. It is hoped to persevere with this unpopular disruption of traditional shooting to check further the validity of this conclusion.

Illegal egg-taking by poachers takes place from time to time, especially on the islands at the south end of Moulting Bay and the island at the southern side of Watson's Bay. It is not possible to assess the extent of this depredation but it is not believed to be great and is controlled by policing. The theft of eggs from nests is not serious as long as all the eggs are removed, as the birds will, after some delay, lay again. It is the practice however to leave one egg in a misguided attempt at conservation. This should be discouraged.

SUMMARY.

1. A list of the main breeding areas in Tasmania is given and the nest, nest building, egg and clutch are described. The mean dimensions of 201 eggs are 10.69 x 6.98 cm. and the average weight is 299.84 g., with a mean volume of 252 cc. The clutch size of 579 clutches in 1962 was 3.89.

2. The incubation period was 39± 2 days and notes are given in the growth rate of cygnets which

may gain weight at a rate of 30g/day, and some young can fly at 60 days from the appearance of the juvenile plumage, though many birds take longer.

3. Aerial surveys to estimate the number of Swans were carried out successfully for small numbers of birds and showed the Port Davey area to be insignificant as a breeding source in 1961-62.

4. Details of the breeding season 1960-62 in Moulting Lagoon are given and floods were found to be the main source of mortality and egg loss. Other factors form a small percentage of the total and inadvertent interference with the nests may render a considerable proportion of these eggs liable to predation or nest abandonment.

5. The breeding success for 1961 and 1962 is tabulated and was 1,330 and 2,657 cygnets respectively. The data gained during banding operations gave a statistical estimate of 1,250 and 2,759 respectively.

6. The principal predation occurs at the egg stage and is carried out mainly by ravens and hawks with mammals being an unimportant subsidiary. The time of lambing on adjacent properties can be important in reducing avian predators, particularly ravens.

7. The open seasons and game management problems are interrelated and show that shooting over the breeding ground has an adverse effect on breeding and an experimental season of shooting with the breeding grounds closed was followed by a successful breeding season.

8. Swans prefer to use island nesting sites and the population using islands statistically is significantly different from that using the mainland. Auto-destruction of habitat is taking place on the islands due to the scratching by birds as they leave the water.

9. Egg management can be used as a means of increasing the effective clutch size.

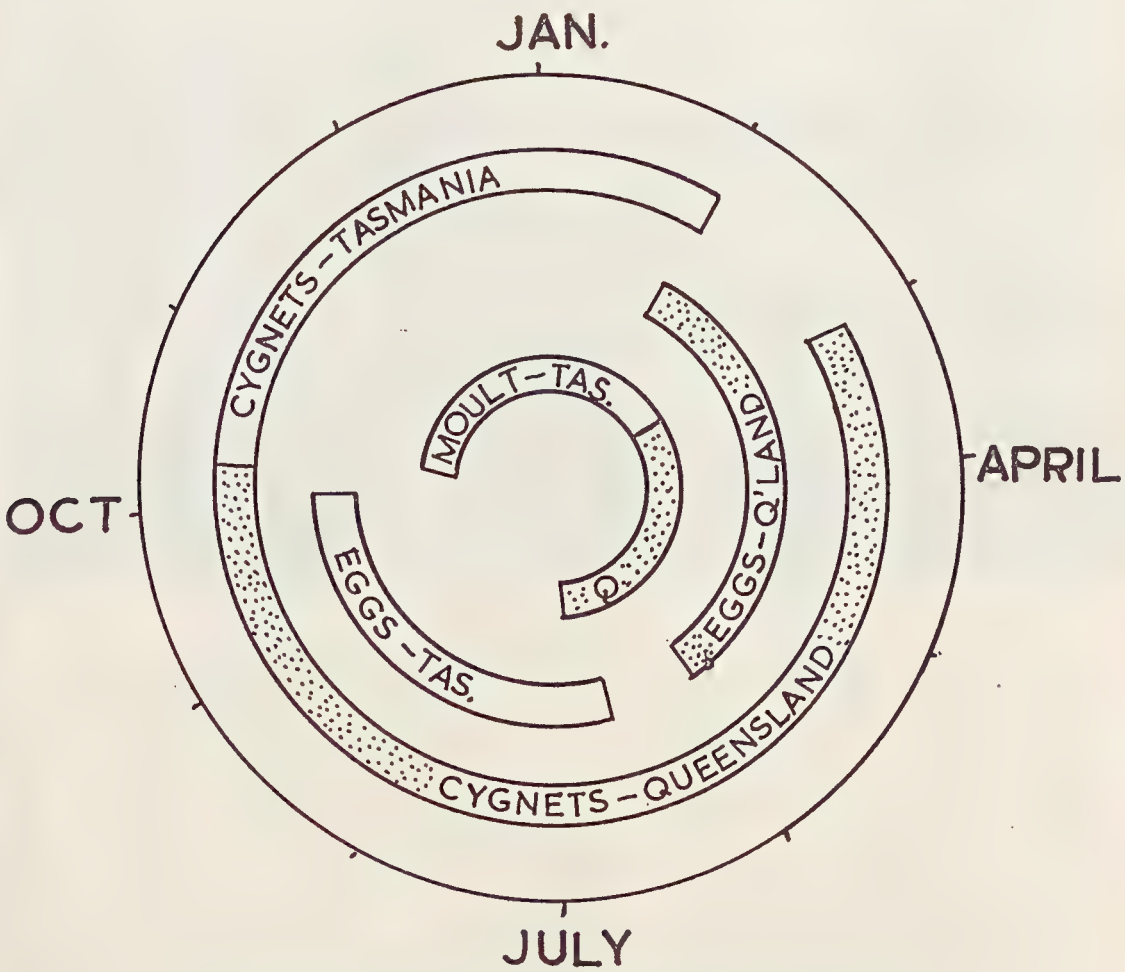

FIG. 7.—Comparison of annual activity of Black Swans in Tasmania and Queensland.

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ADDENDUM

Since the above was written, a paper by Lavery (Wildlife in Australia, 2, pp. 23-5) gives some comparisons with the Queensland Black Swan population. It is apparent that the Queensland birds are lighter in weight than those in Tasmania, Lavery quoting 10 lbs. for the female and 12 for the male. It is also apparent that the breeding success is lower, only about 4 young hatching from 7 eggs per nest. This is attributed to predation by crows. The provision of extra habitat at Bowen has resulted in a large increase in Swan numbers.

The annual activity cycle of the Queensland Swans is sharply different from that in Tasmania (Fig. 7). Egg-laying and the consequent presence of cygnets is almost six months out of phase with the Tasmanian birds. Although the physical presence of rainfall does not stimulate breeding it is clear that both the Tasmanian and Queensland populations of Black Swans breed at times during which the seasonal rains are likely to be encountered, though this is less likely to be important in the Tasmanian population where the rainfall is more equably distributed throughout the year. Drought refuge flocks, important in Queensland, are not identifiable as such at Moulting Lagoon but can be seen at Flinders Island. It appears that the moulting season is much longer at Moulting Lagoon, extending through most of the year but with a peak occurring at post breeding whenever the parent birds undergo moult.

Plate I.—Top Bank Island, Moulting Lagoon, September, 1960. Although very prone to flooding, this island is not the first breeding site to suffer inundation.

Plate II.—General view of Black Swan breeding on part of Cockatoo Island, August, 1961, showing nests and nest markers.

Plate III.—A Lagoon nest constructed of *Chara*, off Top Bank Island, August, 1961.

Plate IV.—Nest of Black Swan, Cockatoo Island, August, 1961. The three eggs in the background are those laid by a "bad mother".

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THE TETRANYCHID MITES OF TASMANIA

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(With 1 plate & 20 figures.)

ABSTRACT

Formerly only four species of the family Tetranychidae had been recorded from Tasmania. Collections of mites from both introduced and native plants have revealed that the family is represented by ten genera of which two are new. Fifteen species, five being new, are now recorded from the State.

The following new genera and species are described:—

New genera—*Synonychus, Tylonychus.*
New species—*Synonychus eucalypti, Eutetranychus acaciae, Tylonychus tasmaniensis, Eotetranychus hudsoni* and *Tetranychus rhagodiae.*

In addition the male of *Schizonobia sycophanta* Wom. is described for the first time.

INTRODUCTION

Mites of the family Tetranychidae are all phytophagous species, many being important pests of cultivated plants throughout the world.

Previously published records have listed only a very few species of tetranychid mites from Tasmania. Evans (1942) listed three introduced species which were of economic importance in the State, and Womersley (1940), in the only review that has been published on this family in Australia, described an apparently native species from Tasmania.

The present paper contains records of fifteen species from Tasmania including five new species. This knowledge has been based on collections over a number of years from both introduced and native plants. Further collecting will probably yield additional species since it is apparent that the fauna of tetranychid mites in the State is richer than was previously thought.

The complete synonymy of previously known species has not been listed since this can be obtained by reference to the comprehensive publication on the family by Pritchard and Baker (1955) and the opinions of Boudreaux and Dosse (1963b) on synonymy in the "*telarius* complex".

Family Tetranychidae Donnadieu 1875

Tétranychidés Donnadieu, 1875, Recher. Serv. Hist. Tetranych., p. 9.

The family Tetranychidae may be recognized by the clawlike fourth palpal segment and by having from 12 to 16 pairs of setae on the dorsum of the idiosoma.

Key to Genera recorded from Tasmania

1.	Propodosoma with four pairs of dorsal setae and hysterosoma with twelve pairs of setae; true claw uncinate and bearing tenent hairs medially	*Bryobia*
	Propodosoma with three pairs of dorsal setae and hysterosoma with nine or ten pairs of setae; true claw padlike with a terminal pair of tenent hairs	2
2.	Empodium with tenent hairs ..	3
	Empodium without tenent hairs	4
3.	Empodium clawlike with a single pair of tenent hairs ...	*Schizonobia*
	Empodium clawlike with two ventrally directed rows of tenent hairs	*Petrobia*
4.	Tarsus I lacking typical duplex setae; but may have a single pair of loosely associated setae dorsally	5
	Tarsus I with two pairs of duplex setae dorsally	6
5.	Empodium clawlike and well developed	*Synonychus*
	Empodium reduced to a tiny rounded protruberance	*Eutetranychus*
6.	Opisthosoma with two pairs of para-anal setae	7
	Opisthosoma with one pair of para-anal setae	9
7.	Empodium clawlike and with three pairs of proximoventral hairs	*Panonychus*
	Empodium not as above	8
8.	Empodium clawlike without proximoventral hairs	*Tylonychus*
	Empodium (excluding legs I and II of male) consisting of three pairs of hairs	*Eotetranychus*
9.	Empodium clawlike, about as long as or longer than proximoventral hairs	*Oligonychus*
	Empodium (excluding legs I and II of male) consisting of three pairs of hairs, the proximordorsal spur short when present	*Tetranychus*

Genus: **BRYOBIA** Koch, 1836

Bryobia Koch, 1836, Deutsch. Crust. Myr. Arach. 1: 8-9.

Mites of the genus *Bryobia* have four pairs of dorsal propodosomal setae and the true claws are hooked with lateral tenent hairs.

The species of this genus recorded from Tasmania are members of what has been known as the "*praetiosa* complex". In recent years overseas acarologists have recognized a number of biotypes of *B. praetiosa* and in some cases have listed morphological characters which have been used to separate several species out of the complex. In Tasmania three species of the "*praetiosa* complex" can be recognized on morphological characters.

1. *Bryobia rubrioculus* (Scheuten)

Sannio rubrioculus Scheuten, 1857, Arch. Naturg. 23 (1): 104.

Eyndhoven (1956) proposed that the name *rubrioculus* Scheuten be applied to the species on fruit trees in Europe. This name has since been used for the species on fruit trees in Japan by Ehara (1959) and in Africa by Baker and Pritchard (1960). Morgan and Anderson (1957) however, questioned the validity of Eyndhoven's action in resurrecting the name *rubrioculus* and therefore proposed a new name, *B. arborea*, for the mite found exclusively on fruit trees in British Columbia. Subsequently Morgan (1960) identified as *arborea*, mites from fruit trees in Holland, England, South Africa, U.S.A., Australia, Chile and Turkey. Thus it is most probable that the two names are being applied to the same species.

As recognized here *rubrioculus* has the following characters:—

Female. Propodosomal lobes deeply cleft, outer lobes with narrow bases, adventitious growths present on lobes. Setae on outer lobes generally reaching the middle of those on inner lobes. Body length (posterior margin of opisthosoma to distal end of propodosomal lobes, excluding dorsal setae) 583-638μ, mean 609μ. Length of leg I (excluding coxa and tarsal claws) 531-676μ, mean 631μ. (In most specimens examined leg I exceeded body length). Lateral distance between paired dorsocentral hysterosomal setae DC_1, 75μ; DC_2, 53μ; DC_3, 37μ.

Larvae. Setae foliaceous in shape similar to dorsal body setae of adult. Lateral distance between paired dorsocentral hysterosomal setae—DC_1, 50μ; DC_2, 23μ; DC_3, 18μ. Distance between bases of first pair of dorsocentral hysterosomal setae approximately twice length of seta.

Male. Unknown—species parthenogenetic.

B. rubrioculus is widespread on fruit trees—particularly pome fruits throughout Tasmania.

Collections examined—

On apple—Huonville, 14.iii.41; Hobart, 5.ii.52; Gordon, 13.xi.52, and 16.x.57; Koonya, 24.xi.56; Ouse, 4.x.57, and 18.xi.58.

On pear—Rowella, 23.viii.49; Launceston, 30.x.59; Middleton, 11.xi.59.

On *Prunus serrulata* Lindl.—Launceston, 12.xii.61.

2. *Bryobia praetiosa* Koch.

Bryobia praetiosa Koch, 1836, Deutsch. Crust. Myr. Arach. 1: 8.

This species occurs on herbaceous plants and is commonly found on clovers in Tasmania. It occasionally invades houses.

As recognized here *B. praetiosa* has the following morphological characters:—

Female. Cleft separating outer propodosomal lobes from inner lobes comparatively shallow, outer lobes wider at base than in *rubrioculus* and often with swellings on inner margin. Propodosomal anterior angulations present. (These are two swellings on the fore margin of the propodosoma just proximad of the lobes. They cannot always be seen in mounted specimens but can be readily seen in unmounted material). Setae on outer lobes generally not reaching beyond bases of those on inner lobes. Body length 825-1001μ, mean 893μ. Length leg I, 734-848μ, mean 782μ. (In all specimens examined leg I was shorter than the body). Lateral distance between paired dorsocentral hysterosomal setae—DC_1, 150μ; DC_2, 139μ; DC_3, 98μ.

Larva. Setae lanceolate in shape, unlike those of adult. Lateral distance between paired dorsocentral hysterosomal setae—DC_1, 96μ; DC_2, 41μ; DC_3, 30μ. Distance between bases of first pair of dorsocentral hysterosomal setae approximately four times length of seta.

Male. Unknown—species parthenogenetic.

Collections examined—

On clover—Bridport, 7.iii.52; Flower Pot, 6.vi.57; Grove, 17.vii.57; New Town, 11.ix.57, and 11.xi.58; Flinders Island, 9.xi.61, and 28.x.63.

On *Spergula arvensis* L.—Grove, 16.viii.57.

On Cyclamen—Hobart, 16.vii.53.

On *Galium aperine* L.—Sandy Bay, 17.viii.64.

In House—Penna, 4.xi.57.

3. *Bryobia kissophila* Eyndhoven

Bryobia kissophila. Eyndhoven, 1955, Ent. Ber. 15: 344.

Eyndhoven (1955) when describing this species was mainly concerned with characters that could be used to separate it from *rubrioculus* on apple and pear. It is however more difficult to distinguish between *kissophila* and *praetiosa*. Characters of *kissophila* which may be used for this purpose are:—

Female. Cleft separating outer propodosomal lobes from inner lobes rather deep, outer lobes wide at base and somewhat triangular in shape. Setae on outer lobes approximately 1½ to 2 times as long as those on inner lobes. Body length 836-891μ, mean 860μ. Length of leg I, 811-856μ, mean 834μ. Lateral distance between paired dorsocentral hysterosomal setae, DC_1, 120μ; DC_2, 81μ; DC_3, 68μ.

Larva. Setae lanceolate in shape unlike those of adult. Lateral distance between paired dorsocentral hysterosomal setae, DC_1, 90μ; DC_2, 37μ; DC_3, 24μ. Distance between bases of first pair of dorsocentral hysterosomal setae approximately 2½ times length of seta.

B. kissophila is apparently confined to ivy, *Hedera helix* L. Collections from this host have been examined from Hobart, 21.vii.57 and 7.ix.61.

Morgan (1960) plotted the distances between the paired dorsocentral hysterosomal setae and showed that there was a different pattern between *arborea* and *praetiosa*. He then stated that in adults of *arborea*, DC_2 always lies mesad of an imaginary line joining DC_1 and DC_3, whereas in *praetiosa*, DC_2 was laterad of this line. In this statement it is assumed that the position of the paired DC_2 setae is midway between DC_1 and DC_3.

In Tasmanian specimens however the paired DC_2 setae do not lie midway between DC_1 and DC_3, thus the pattern cannot be determined by direct examination. Nevertheless the position of the dorsocentral hysterosomal setae is a useful character to aid in species separation within the complex in Tasmania. Instead of plotting the pattern by artificially placing DC_2 midway between DC_1 and DC_3 (Morgan 1960), the lateral distances between the three sets of paired dorsocentral hysterosomal setae are measured and the ratio $R = \frac{DC_1 - DC_3}{DC_2 - DC_3}$ determined. Values of $R > 2$ are found in all stages of *rubrioculus, kissophila,* and in the immature stages of *praetiosa,* whereas values of $R < 2$ are found in adults of *praetiosa.*

Genus: **SCHIZONOBIA** Womersley, 1940

Schizonobia Womersley, 1940, Trans. Roy. Soc. S. Aust. 64 (2) 251.

Womersley's description of the genus was—"Roundish species dorsally strongly convex with strong dorsal setae arising from papillae. Mandibles styliform with distinct mandibular plate. Palpi stout with strong tibial claw. Peritreme almost straight but ending externally in a very large globular chamber. Legs not excessively long, tarsi about two-thirds length of tibiae, claws modified as two pads ending in paired tenent hairs, empodium clawlike but only with one pair of lateral tenent hairs".

This description should however be expanded in the following manner:—

Female tarsus I with two pairs of duplex setae adjacent at distal end, tarsus II with single pair of duplex setae. Male tarsus I with two pairs of duplex setae adjacent at distal end and up to four pairs of duplex setae along dorsum of tarsus; tibia I with up to eight pairs of duplex setae. Tarsus II with a single pair of duplex setae.

Beer and Lang (1957) proposed the genus *Schizonobiella* for the species *S. aeola* Beer and Lang, which they recognized as having considerable affinity to *Schizonobia* Womersley. The degree of affinity between these two genera is even greater than Beer and Lang were in a position to judge since the previously undescribed male of *Schizonobia sycophanta* also has the unusual character of possessing numerous pairs of duplex setae on both tarsus I and tibia I.

1. *Schizonobia sycophanta* Womersley

(Figs 1, 2 and 3. Plate 1)

Schizonobia sycophanta Womersley, 1940, Trans. Roy. Soc. S. Aust. 64 (2): 251.

This species was originally described from females collected in Tasmania. In his description Womersley (1940) listed the locality and host as "attacking couch grass Hobart, Tasmania, 1939 (J.W.E.)".

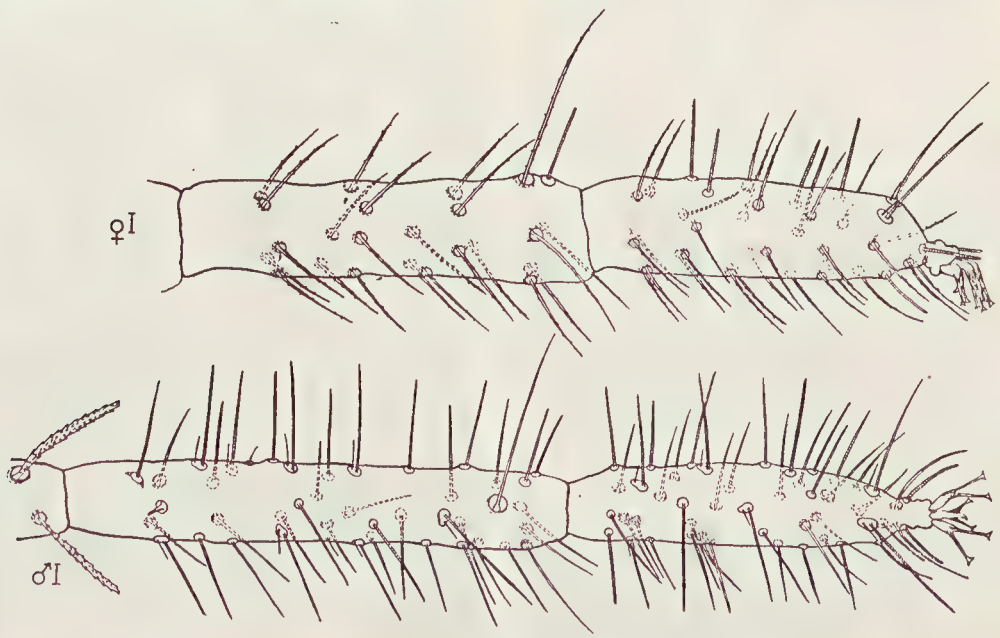

FIG. 1.—*Schizonobia sycophanta* Wom. Tibia and Tarsus I of male and female.

FIG. 2.—*Schizonobia sycophanta* Wom. Empodium I, female.

I was unable to locate this mite in Tasmania until an examination of departmental files revealed that the original collection had been made by Dr. J. W. Evans from corn spurry, *Spergula arvensis* L., at Cygnet, and not from "couch grass Hobart" as stated by Womersley.

S. sycophanta is of widespread occurrence on corn spurry during the winter and has not been collected from any other host.

Because of certain inaccuracies in the original description of the female, a redescription has been included. In addition the male is described for the first time.

Female. Colour in life reddish. Rostrum short reaching middle of femur I. Palpus stout with claw not reaching to end of fifth segment. Peritreme short ending externally in a globular enlargement consisting of a complex series of branches arising from a basal trunk. Legs with large numbers of short finely pubescent tactile setae. Leg I almost as long as body, leg II two-thirds length of leg I. Tarsus I with two pairs of duplex setae adjacent at distal end and twenty-three tactile and six sensory setae distinctly proximal to the duplex setae. Tibia I with twenty-three tactile setae, one of which is much longer than the rest, and one distal sensory seta. Tarsus II with a single pair of duplex setae and seventeen tactile and one sensory setae proximal to duplex setae; Tibia II with seventeen tactile setae. Empodium uncinate with a single pair of ventrally directed hairs borne medially. Body strongly convex, dorsal integument coarsely striated; dorsal setae similar in length, strong, ciliated, and blunt, approximately as long as intervals between their bases, set on strong tubercles. Propodosoma with three pairs of dorsal setae, hysterosoma with ten pairs including three pairs of dorsolaterals.

Length of body 900μ; including rostrum 979μ, width 671μ.

Male. Similar to female but body less rounded. Leg I longer than body. Tarsus I with two pairs of duplex setae adjacent at distal end and a further four pairs of duplex setae on dorsal surface of tarsus; fourteen smooth tactile setae and twenty-one sensory setae proximal to distal duplex setae; sensory setae largely on dorsal surface. Tibia I with about eight pairs of duplex setae along dorsal surface of segment; twelve tactile setae of which one near the distal end is much longer than rest and two of the remainder are very short; twenty-one sensory setae and one very short sensory spine near proximal end of segment. Dorsal surface of genu and femur I bearing strong ciliated setae similar to those on dorsum of body. Tarsus II with a single pair of duplex setae, twenty tactile and two sensory setae. Tibia II with nineteen tactile setae. Dorsal integument of body less coarsely striated than in female. Aedeagus long slender, slightly curved and tapering to a fine point. Length of body 619μ; including rostrum 707μ; width of body 398μ.

Collections examined—

On *Spergula arvensis* L.—*Cygnet, 1939, J. W. Evans; Grove, 16.viii.57 and 22.iv.58; Margate, 13.ix.57; Spreyton, July 1959; Gravelly Beach, 19.vii.54.

* Part of collection from which original description was made.

FIG. 3.—*Schizonobia sycophanta* Wom. Palp and aedeagus, male.

There is considerable variation in the number of duplex setae on the male tarsus I and tibia I and also in the length of the proximal member of the pairs.

Although *S. sycophanta* was described from Tasmania the only host on which it has been collected is corn spurry, an introduced weed of European origin. It is therefore not certain whether the species is truly native.

During the winter and early spring all stages of the mite may be found on corn spurry. The species apparently aestivates as an egg since the active stages disappear during the summer but large numbers of eggs remain on the dried off stems of the host plants. The eggs are red and of a more or less spherical shape with a whitish striated top.

Genus: **PETROBIA** Murray, 1877

Petrobia Murray, 1877, Econ. Ent. Aptera, p. 118.

The true claws in this genus are modified to pads, each bearing a pair of tenent hairs distally, whereas the empodium is uncinate with two rows of ventrally directed tenent hairs.

1. *Petrobia latens* (Muller)

Acarus latens Muller, 1776, Zool. Dan. Prodr. p. 187.

Petrobia latens is mainly a grass or cereal infesting species that is more or less cosmopolitan in distribution. Womersley (1940) recorded it from N.S.W. and Western Australia. In Tasmania it has been found in widely scattered areas but in no case has it achieved the status of an economic pest.

Collections examined—

On clover—Bridport, 7.iii.52; Cressy, 18.xii.56.
On pasture—Swansea, 28.xi.59; Sheffield, 27.iii.63.
On onion—Scottsdale, 14.i.63.
On bracken, *Pteridium esculentum* (Forst. f.) Nakai—Cradoc, 2.iv.64.

Genus: **SYNONYCHUS** gen. n.

Type of genus—*Synonychus eucalypti* sp. n.

The genus *Synonychus* is proposed for a single species that is allied to both *Eurytetranychus* Oudemans and *Eutetranychus* Banks. Like these latter genera, mites of the genus *Synonychus* lack, on tarsi I and II the duplex setae characteristic of other genera of the family Tetranychidae. In *Synonychus*, however, the empodium is a stout clawlike member approximately half as long as the tenent hairs of the true claws, whereas in *Eurytetranychus* the empodium is reduced to a rudimentary uncinate projection and in *Eutetranychus* it is virtually absent, being reduced to only a tiny knob.

The body is oval with short slender legs. There are three pairs of dorsal propodosomal setae, ten pairs of dorsal hysterosomal setae and two pairs of para-anal setae. The inner sacrals are further apart than the third pair of dorsocentrals.

1. *Synonychus eucalypti* sp. n.
(Figs. 4, 5 and 6)

Female. Colour in life brownish yellow. Palpus with terminal sensillum stout, approximately twice as long as broad. Peritreme terminating in a simple enlargement. Legs slender shorter than body. Tarsus I lacking duplex setae but with six tactile and five sensory setae, the latter being all on distal half of segment; two of the distal tactile setae pectinate. Tibia I with five tactile and one sensory setae. Empodium a stout clawlike member approximately half as long as the tenent hairs of the true claws. Tarsus II lacking duplex setae but with a total of five tactile and five sensory setae of which only one tactile and one sensory setae are on proximal half of segment, and one pair of the distal tactile setae are pectinate. Tibia II with five tactile setae. Body oval in shape, dorsal integument with fine striae. Hysterosoma with a pore caudo-laterad of first dorsolateral setae. Dorsal setae short, blunt and serrate, inner sacrals wider apart than third pair of dorsocentrals, outer sacrals only slightly further apart than inner sacrals, two pairs of para-anal setae. Length of body 338μ, greatest width 230μ.

Male. Similar to female but body more tapered. Palpus with terminal sensillum smaller and more slender than in female. Tarsus I without duplex setae but with five tactile setae, one pair of which are pectinate, and seven blunt sensory setae. Tibia I with five tactile and two blunt sensory setae. Tarsus II lacking duplex setae but with five tactile setae of which two at distal end are pectinate and seven blunt sensory setae. Tibia II with five tactile setae. Inner and outer sacrals approximately the same distance apart and both are further apart than the third pair of dorsocentrals. Outer sacral setae one and one half times as long as inner sacrals. Aedeagus curving gradually dorsad with a slightly sigmoid tip. Length of body 257μ; greatest width 171μ.

FIG. 4.—*Synonychus eucalypti* sp. n. Dorsal aspect of female.

Holotype. Female, on *Eucalyptus ovata* Labill, Franklin, Tasmania 21.viii.63, in Australian National Insect Collection, Canberra, A.C.T.

Paratypes. Five males, forty-four females, same data as holotype, in Australian National Insect Collection, Canberra, A.C.T.; South Australian Museum, Adelaide, S.A.; and Department of Agriculture, Hobart, Tasmania.

Womersley (1940) erected the genus *Anatetranychus* for the species *A. hakea.* Subsequently Pritchard and Baker (1955) placed *Anatetranychus* in synonymy with *Neotetranychus* Tragardh, basing their opinion on the published description but recognizing that the female of *hakea* differed from other members of the genus *Neotetranychus* in that the empodia were described as being simply clawlike.

It is not clear from Womersley's description however, whether the female of *hakea* possesses duplex setae on tarsi I and II. If not, then *Anatetranychus* Womersley could not be placed in synonymy with *Neotetranychus* Tragardh and the genus *Synonychus* here proposed might prove to be a synonym of *Anatetranychus.*

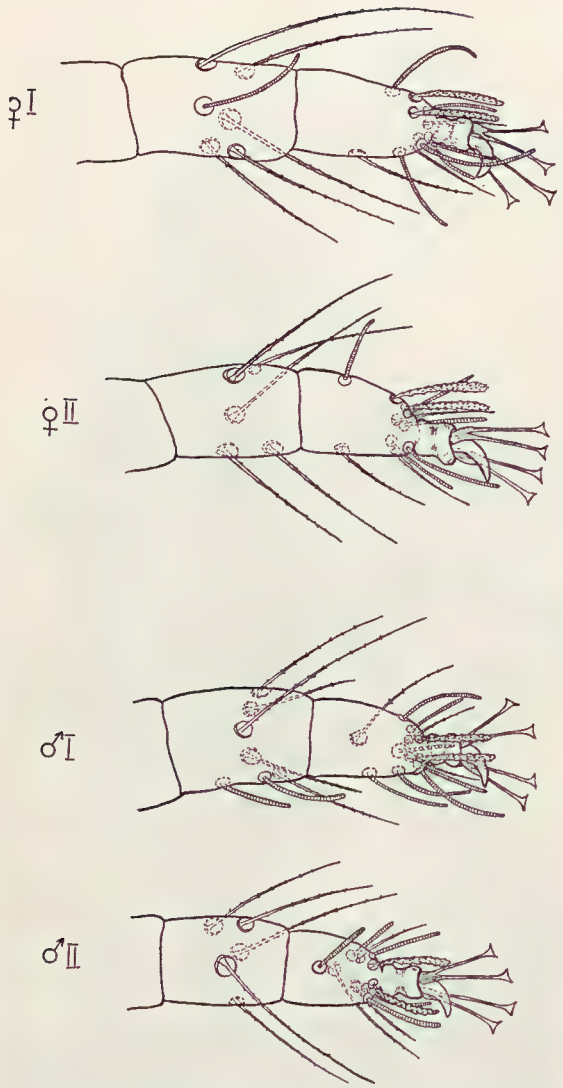

FIG. 5.—*Synonychus eucalypti sp.n.* Tibia and Tarsus I and II, male and female.

Unfortunately the type of *Anatetranychus hakea* Womersley could not be located in the South Australian Museum nor has it been possible to locate any material of the species in any other Australian institution. Thus until topotype material is collected from *Hakea* sp. in Western Australia the problem cannot be resolved.

Genus: **EUTETRANYCHUS** Banks, 1917

Neotetranychus (*Eutetranychus*) Banks, 1917, Ent. News. 28: 197.

The genus *Eutetranychus* may be recognized by the rudimentary empodium which is reduced to a tiny knob. Tarsi I and II lack the characteristic duplex setae and the hysterosoma bears a pore caudo-laterad of the first dorsolateral setae.

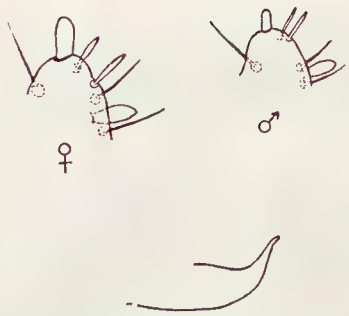

FIG. 6.—*Synonychus eucalypti* sp. n. Palps—male and female, and aedeagus.

1. *Eutetranychus acaciae* sp. n.

(Figs. 7, 8, 9, and 10)

Eutetranychus acaciae shows some similarity to the polytypic *E. banksi* (McGregor). It differs however, in the shape of the dorsal setae, the setation of the legs and the shape of the palpus.

Female. Colour in life pinkish yellow with dark marginal spots. Stylophore with shallow mediodorsal furrow distally. Palpus with a tubercle exterior to dorsal chaeta on first segment, terminal sensillum slender almost four times as long as broad. Peritreme ending in a simple enlargement. Legs all shorter than body. Tarsus I with thirteen tactile and four sensory setae; without duplex setae. Tibia I with eight tactile and one short, blunt sensory setae. Tarsus II with twelve tactile and three sensory setae; without duplex setae. Tibia II with four tactile setae. Tarsi III and IV each with a pair of pectinate tactile setae distally. Empodium reduced to a very tiny knob. Propodosoma with mediodorsal striae longitudinal and finely granulate, hysterosoma with dorsal integument irregularly striate. Idiosoma with dorsal setae strong, serrate, rodlike, borne on strong tubercles; inner sacrals of similar length to dorsocentrals and much longer than outer sacrals or clunals. Length of body 427μ; greatest width 336μ.

Male. Similar to female but body more slender and tapering and legs longer relative to body. Terminal sensillum of palpus short and slender. Tarsus I with twelve tactile and seven sensory setae, mainly on distal half of segment; without duplex setae. Tibia I with nine tactile and four short blunt sensory setae. Tarsus II with ten tactile and five sensory setae. Tibia II with five tactile and two sensory setae. Idiosoma with propodosomal and dorsolateral setae approximately twice length of dorsocentral setae. Inner sacrals of similar length to dorsocentrals and appreciably longer than outer sacrals or clunals. Aedeagus curved abruptly dorsad with blunt tip. Length of body 302μ; greatest width 216μ.

Holotype—Female, on *Acacia dealbata* Link, Hayes, Tasmania, 23.viii.63, in the Australian National Insect Collection, Canberra, A.C.T.

Paratypes—Eight males, thirteen females, on *Acacia dealbata* Link, Hayes, Tasmania, 23.viii.63, 29.viii.63, 10.x.63, 10.ix.64, and 14.xii.64, in the

Australian National Insect Collection, Canberra, A.C.T., South Australian Museum, Adelaide, S.A., and Department of Agriculture, Hobart, Tasmania.

Genus: **PANONYCHUS** Yokoyama, 1929

Panonychus Yokoyama, 1929, Saishin Nippon Sangyo Gaishu Zensho: 531.

The genus *Panonychus* may be recognized by having the dorsal setae arising from strong tubercles and a clawlike empodium with three pairs of proximo-ventral hairs.

1. *Panonychus ulmi* (Koch)

Tetranychus ulmi Koch, 1836, Deutsch. Crust. Myr. Arach. 1: 11.

Metatetranychus ulmi (Koch) Oudemans, 1931, Ent. Ber. 8 (177): 198; Womersley, 1940, Trans. Roy. Soc. S. Aust. 64 (2): 261.

This species, the European red mite, is of widespread occurrence in Tasmania being an important pest on apples.

FIG. 7.—*Eutetranychus acaciae* sp. n. Dorsal aspect of female, and peritreme.

FIG. 8.—*Eutetranychus acaciae* sp. n. Dorsal aspect of male, aedeagus, and male and female palps.

The first reference in a taxonomic paper to the occurrence of this species in Tasmania was by Womersley (1940) but it had obviously become established in the State much earlier since it was already a widespread economic pest in 1935 (Miller 1949).

Collections examined—

On apple—Margate, 6.ii.40, and 7.ii.42; Grove, 18.ix.50, and 8.xi.50; Hobart, 4.iv.52, and 20.v.52; Cygnet, 15.iii.55; Castle Forbes Bay, 14.i.57.

On Rowan, *Sorbus aucuparia* L. —Hobart, 5.xii.56.

Genus: **TYLONYCHUS** gen. n.

Type of genus *Tylonychus tasmaniensis* sp. n.

The genus *Tylonychus* is proposed for a single species the affinities of which are obscure. It is probably closest to *Neotetranychus* Tragardh and could perhaps be placed in that genus if one accepted the action of Pritchard and Baker (1955) in synonymizing the species *Anatetranychus hakea* Womersley in *Neotetranychus* even though the empodium was described as simply clawlike, whereas the empodia of females of all other species in *Neotetranychus* have long curved bases dividing distally into paired hairs.

In my opinion species in which the empodia of the females are clawlike (i.e., undivided) should not be included in *Neotetranychus*. Even so, however,

the relationship of *Tylonychus* to *Anatetranychus* cannot be determined until topotype material of *A. hakea* is obtained (see discussion on the genus *Synonychus*).

Mites of the genus *Tylonychus* are unusual in the excessively long and slightly downwardly curved gnathosoma. The dorsal integument of the female bears coarse striae with numerous irregularly shaped spinules. The dorsal setae are stout and heavily pilose, arising from strong tubercles and there are two pairs of short pilose para-anals. There are two pairs of duplex setae adjacent on tarsus I and a single pair on tarsus II. The dorsal setae of the legs are short and pilose arising from tubercles. The empodium of all legs in both sexes is a simple curved claw.

1. *Tylonychus tasmaniensis* sp. n.

(Figs. 11, 12, 13 and 14)

Female. Colour in life purplish sometimes almost black. Palpus with terminal sensillum slender three times as long as broad; other sensillae rodlike and slightly curved. Peritreme hooked distally. Tarsus I with two pairs adjacent duplex setae and three tactile setae proximad of the proximal pair of duplex setae. Tibia I with six tactile setae and one sensory seta. Tarsus II with three tactile setae proximal to the single pair of duplex setae. Tibia II with five tactile setae. Tarsus III with seven tactile setae and one short sensory seta. Tibia III with four tactile setae. Tarsus IV with seven tactile setae and one short sensory seta. Tibia IV with four tactile setae. Empodia on all legs stout, curved, clawlike. Dorsal tactile setae on all legs stout and pilose. Stylophore long narrow, rounded anteriorly. Body tapering posteriorly, gnathosoma long and curved slightly ventrad. Dorsal integument with coarse striae bearing irregularly shaped spinules. Dorsal setae stout and pilose arising from strong tubercles. Dorsocentral setae slightly longer than longitudinal

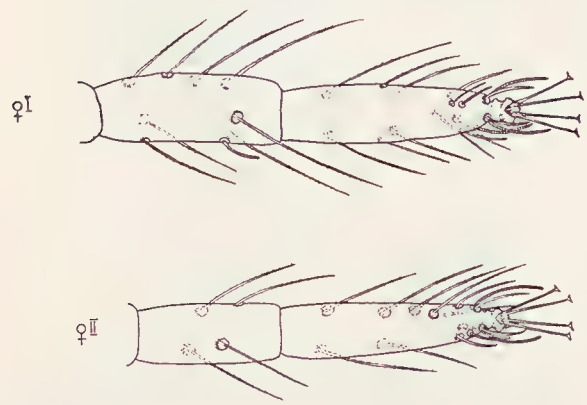

FIG. 9.—*Eutetranychus acaciae* sp. n. Tibia and Tarsus I and II, female.

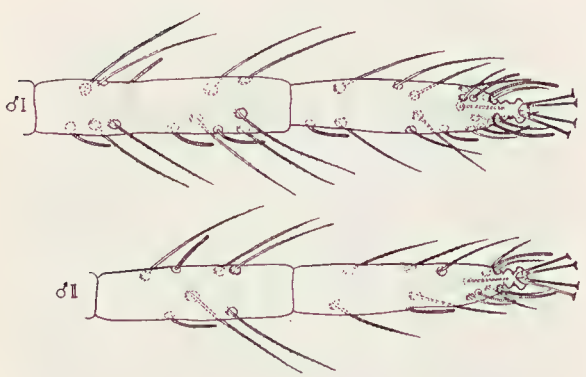

FIG. 10.—*Eutetranychus acaciae* sp. n. Tibia and Tarsus I, male.

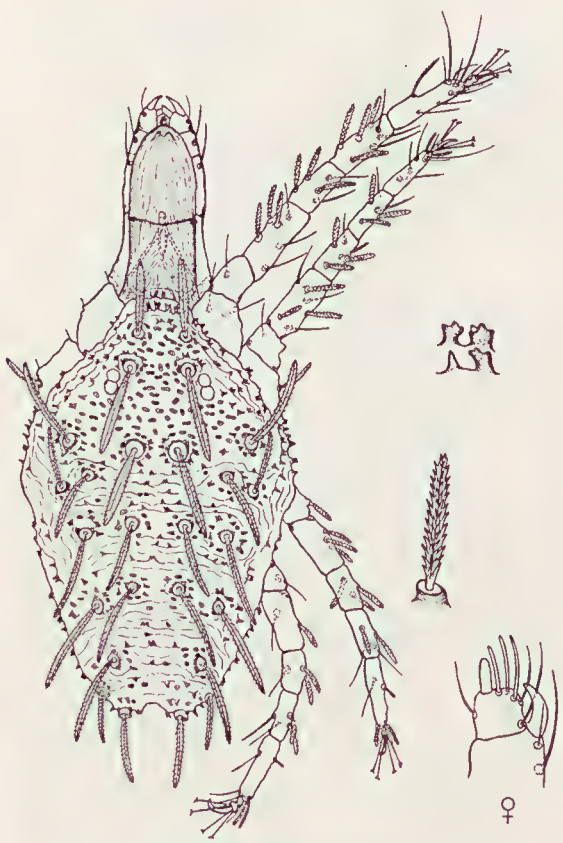

FIG. 11.—*Tylonychus tasmaniensis* sp. n. Dorsal aspect of female and palp.

FIG. 12.—*Tylonychus tasmaniensis* sp. n. Dorsal aspect of male, and aedeagus.

distance between them. Inner sacrals almost as far apart as outer sacrals and approximately twice as long as latter setae. Two pairs of short pilose para-anal setae. Length of body 279μ; greatest width 185μ.

Male. Precise details of distal segment of palpus not observable; first segment with stout sensory seta distad on dorsal surface. Peritreme hooked distally. Legs longer than body. Tarsus I with two pairs adjacent duplex setae, and three tactile and two sensory setae proximad of the proximal pair of duplex setae. Tibia I with seven tactile and two sensory setae. Tarsus II with two tactile and two sensory setae proximal to the single pair of duplex setae. Tibia II with five tactile setae. Tarsus III with seven tactile and one short sensory setae. Tibia III with four tactile setae. Tarsus IV with seven tactile and one short sensory setae. Tibia IV with four tactile setae. Empodia on all legs stout, curved, clawlike. Dorsal tactile setae on legs stout and pilose. Dorsal integument coarsely striate and wrinkled but lacking spinules. Propodosoma with a reticulate pattern medially. Dorsal setae, stout, pilose, arising from strong tubercles. Dorsocentral hysterosomal setae approximately as long as longitudinal interval between them. Inner sacrals approximately twice length of outer sacrals. Aedeagus as figured, sickle shaped, curved abruptly dorsad and tapering to tip. Length of body 225μ; greatest width 144μ.

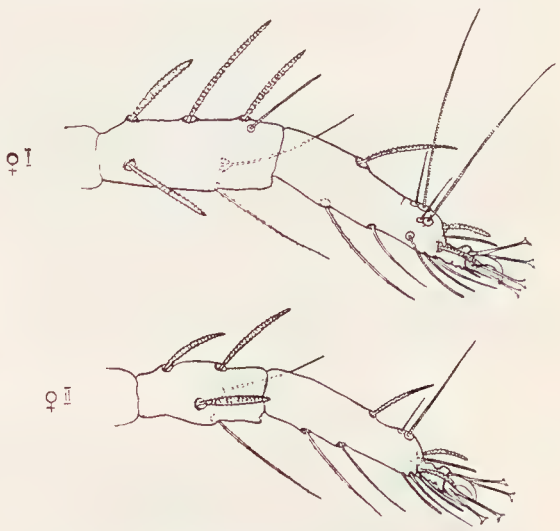

FIG. 13.—*Tylonychus tasmaniensis* sp. n. Tibia and Tarsus I and II, female.

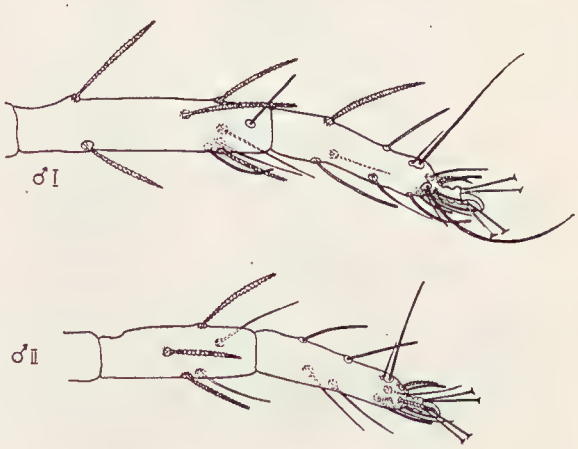

FIG. 14.—*Tylonychus tasmaniensis* sp. n. Tibia and Tarsus I and II, male.

Holotype. Female, on *Acacia mearnsii* de Wild, Hayes, Tasmania, 19.ix.63 in the Australian National Insect Collection, Canberra, A.C.T.

Paratypes. One male, five females, on *Acacia mearnsii* deWild, Hayes, Tasmania, 19.ix.63, 4.iv.64, and 29.iv.64. Sixteen females on *Acacia dealbata* Link, Hayes, Tasmania, 29.viii.63, 10.x.63, 21.xi.63, and 10.ix.64, in the Australian National Insect Collection, Canberra, A.C.T., South Australian Museum, Adelaide, S.A. and Department of Agriculture, Hobart, Tasmania.

Genus: **EOTETRANYCHUS** Oudemans, 1931

Eotetranychus Oudemans, 1931, Ent. Ber. 8 (178): 224.

Mites of the genus *Eotetranychus* may be recognized by having two pairs of para-anal setae, by the empodium consisting of three pairs of hairs (except on leg I and sometimes leg II of the male) and by having the duplex setae on tarsus I adjacent.

1. *Eotetranychus hudsoni* sp. n.

(Figs. 15 and 16)

This species is somewhat similar to *Eotetranychus mandensis* Manson, in the shape of the aedeagus but differs in the shape of the male palpus and the setation of the body and legs.

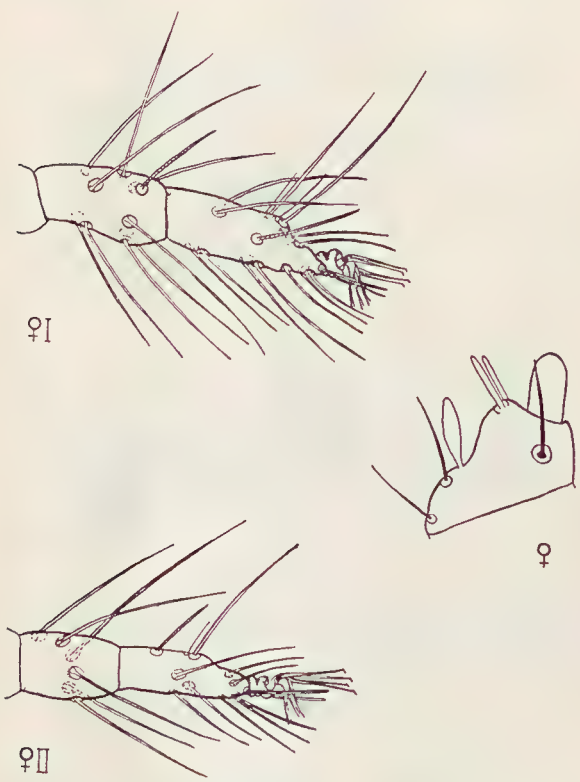

Fig. 15.—*Eotetranychus hudsoni* sp. n. Tibia and Tarsus I and II, palp—female.

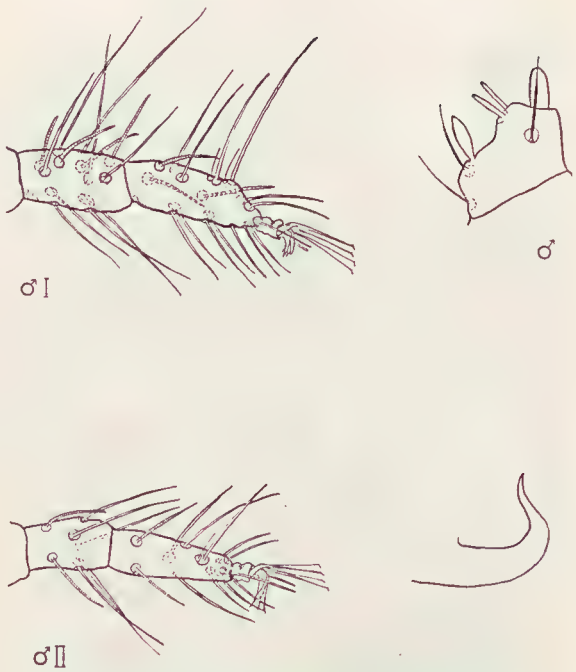

Fig. 16.—*Eotetranychus hudsoni* sp. n. Tibia and Tarsus I and II, palp and aedeagus—male.

Female. Colour in life yellow with dark marks along sides of body. Palpus with terminal sensillum stout, twice as long as broad. Peritreme straight distally terminating in a simple bulb. Tarsus I with thirteen tactile and one sensory setae in addition to the two pairs of adjacent duplex setae. Tibia I with nine tactile and one sensory setae. Tarsus II with ten tactile and one sensory setae in addition to a pair of duplex setae. Tibia II with six tactile setae. Tarsus III with eight tactile and one sensory setae. Tibia III with four tactile setae. Tarsus IV with eight tactile and one sensory setae. Tibia IV with six tactile setae. Dorsal body setae long and tapering. Dorsocentral hysterosomal setae about twice as long as the longitudinal distance between them. Dorsal striae transverse between third pair of dorsocentral hysterosomals. Striae on and anterior to genital flap transverse. Length of body 360μ; greatest width 270μ.

Male. Palpus with terminal sensillum stout approximately twice as long as broad. Peritreme straight distally terminating in a simple bulb. Tarsus I with thirteen tactile and three sensory setae in addition to the two pairs of adjacent duplex setae. Tibia I with nine tactile and four sensory setae. Empodium I bifid, each side being tridigitate with the ventral member much larger than the other two. Tarsus II with ten tactile and two sensory setae in addition to the single pair of duplex setae. Tibia II with five tactile and two sensory setae. Empodium II with three pairs of hairs of which the ventral are strongest. Tarsus III with eight tactile and one sensory setae. Tibia III with five tactile and one sensory setae. Tarsus IV with eight tactile and one sensory setae. Tibia

IV with six tactile and one sensory setae. Aedeagus as figured, slender, tapering, bent abruptly dorsad with tip curved slightly posteriorly. Length of body 261μ, greatest width 167μ.

Holotype. Male, on *Xerotes longifolia* R. Br., Lindisfarne, Tasmania, 2.v.63, in the Australian National Insect Collection, Canberra, A.C.T.

Paratypes. Six males, fourteen females, on *Xerotes longifolia* R. Br., Lindisfarne, Tasmania, 29.iv.63, and 2.v.63, in the Australian National Insect Collection, Canberra, A.C.T., South Australian Museum, Adelaide, S.A., and Department of Agriculture, Hobart, Tasmania.

Genus: **OLIGONYCHUS** Berlese, 1886

Oligonychus Berlese, 1886, Acari. Dann. Piante. Coltiv. p. 24.

The genus *Oligonychus* may be recognized by the well developed clawlike empodium bearing proximoventral hairs and the absence of the caudal pair of para-anal setae.

A single species of the genus occurs commonly on oaks, *Quercus* sp., in Tasmania.

The specific identity of this species is in doubt. The aedeagus and palpus of the male, and the palpus of the female are similar to those figured by Hirst (1920) for a mite which he identified as *Oligonychus quercinus* (Berlese) from oaks in England. This similarity is further borne out by a comparison I have made of females of the mite from Tasmania with these forming part of the original collection made by Hirst from oaks at Wimbledon, England.

Pritchard and Baker (1955) however considered that *quercinus* Berlese was a synonym of *Eotetranychus aurantii* (Targioni Tozzetti), and that Hirst's *quercinus* was a misidentification of *O. brevipodus* (Targioni Tozzeti). They also expressed the opinion that the specific status of *O. brevipodus* must be based on topotype material.

Wainstein (1960) recorded and figured *O. brevipodus* from Kazakhstan and listed *O. quercinus* (Berlese) sensa Hirst, as a synonym. The mite he figured is quite unlike Hirst's material which I have examined. Thus if Wainstein is correct in his diagnosis of *brevipodus* the mite identified as *quercinus* by Hirst is a different species.

Since the species on oaks in Tasmania is most probably introduced, its specific identity must remain in doubt until the problem of the species of this genus on oaks in England and Europe is resolved. Meanwhile the species in Tasmania has been provisionally identified as *Oligonychus brevipodus?* (Targioni Tozzetti). The description is as follows: —

1. *Oligonychus brevipodus?* (Targioni Tozzetti)

(Figs. 17 and 18)

Heteronychus? brevipodus Targioni Tozzetti, 1878, Ann. Agric. 1: 255.

Female. Colour in life yellow with black markings. Palpus with terminal sensillum stout, one and one half times as long as broad, dorsal sensillum short and slender. Peritreme straight distally ending in a bulb. Tarsus I with three tactile and one sensory setae distinctly proximad of proximal pair of duplex setae. Tibia I with seven tactile and one sensory setae. Empodium I with a strong curved claw and four (sometimes apparently three) pairs of proximoventral hairs. Tarsus II with two tactile and one sensory setae distinctly proximad of the duplex setae, and two tactile setae more or less in line with the duplex setae. Tibia II with five tactile setae. Stylophore slightly emarginate anteromedially. Dorsal integument of hysterosoma with striae lobed and transverse except for longitudinal striae between third pair of dorsocentrals. Dorsal setae of idiosoma long, slender, tapering, and serrate. Dorsocentral hysterosomal setae more than twice as long as the longitudinal distance between their bases. Para-anal setae longer than clunals. Length of body 261μ; greatest width 189μ

Male. Similar to female. Palpus with terminal sensillum rudimentary. Tarsus I with three tactile and two sensory setae distinctly proximad of proximal pair of duplex setae, and one sensory seta approximately in line with that pair of duplex setae. Tibia I with seven tactile and two sensory setae. Tarsus II with three tactile and one

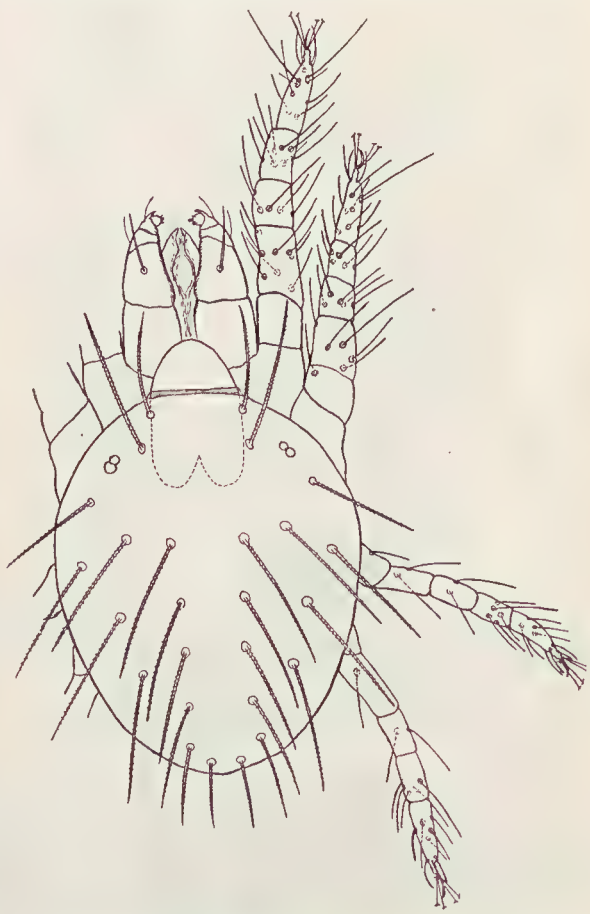

FIG. 17.—*Oligonychus brevipodus* ? (Targioni Tozzetti), dorsal aspect of female.

sensory setae proximad of duplex setae and two tactile setae approximately in line with duplex setae. Tibia II with five tactile setae. Dorsal integument of hysterosoma with transverse striae. Aedeagus as figured, bent gradually ventrad, distal end narrow. Length of body 243μ; greatest width 149μ.

Collection examined—

On Oak, *Quercus* sp., Kingston, 5.xi.57; Cradoc, 11.xi.57; New Norfolk, 25.i.63, and 8.ii.63.

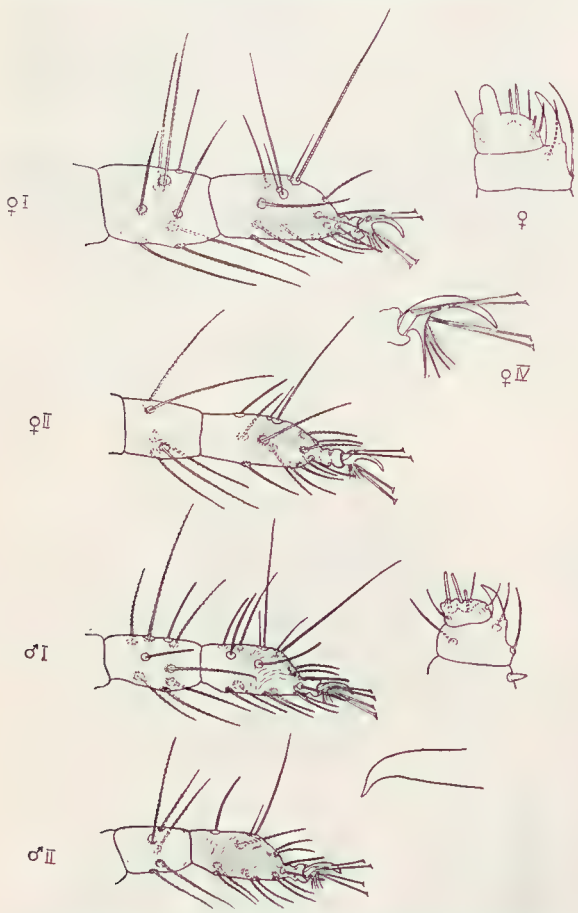

FIG. 18.—*Oligonychus brevipodus* ? (Targioni Tozzetti), Tibia and Tarsus I and II; palps—male and female; empodium IV, female; and aedeagus.

Genus: **TETRANYCHUS** Dufour, 1832

Tetranychus Dufour, 1832, An. Sci. Natl. Paris 25: 276.

Mites of the genus *Tetranychus* have only one pair of para-anal setae and the empodium of the female consists of three pairs of proximoventral hairs above which there is a small or rudimentary spur. The duplex setae on tarsus I are widely separated. Empodium I of the male usually consists of a pair of tridigitate appendages with or without a mediodorsal spur.

The taxonomy of this genus has been very confused owing to the large number of closely related species. In addition there have been long existing nomenclatural problems particularly within what has been known as the "*telarius* complex".

Boudreaux (1956) and Boudreaux and Dosse (1963a) have shown the value of the cuticular lobes of summer females in aiding species separation particularly within the "*telarius* complex". More recently (1963b) they have attempted to clarify and stabilize the names of species within the complex.

1. *Tetranychus lambi* Pritchard and Baker

Tetranychus lambi Pritchard and Baker, 1955, Pac. Coast Ent. Soc. Mem. Ser. 2: 399.

The females of *T. lambi* have transverse striae between the third pair of dorsocentral hysterosomals and longitudinal striae between the inner sacral setae. The empodia of both males and females lack mediodorsal spurs. The aedeagus has the axis of the knob parallel to the axis of the shaft, slender, the anterior angulation acute and pronounced, the caudal angulation very slender and acute.

This species was described from New Zealand on apple and strawberry, but, to date, it has been collected only from two species of native plants in Tasmania.

Collections examined—

On *Amperea spartioides* Bron., Lindisfarne, 22.vii.63.

On *Goodenia ovata* Sm., Nubeena, 7.iii.63.

2. *Tetranychus ludeni* Zacher

Tetranychus ludeni Zacher, 1913, Mitt. kais. biol. Anst. Lan.-Forstw. 14: 40.

Summer females of *T. ludeni* are carmine red in colour. In females of this species the proximal pair of duplex setae on tarsus I are in line with most other proximal setae. The dorsal cuticular lobes are small, narrow and pointed at the tip, separated by spaces at the bases. Ventral lobes are broad and low and extend anteriorly to the region of the ventral propodosomal setae. The aedeagus of the male has a gradual dorsal curve, the distal knob is small with an acute anterior angulation but with virtually no posterior angulation.

In Tasmania this species has been encountered both out of doors and in greenhouses.

Collection examined—

On French beans, Lutana, 29.iii.56, and 22.vi.56. In greenhouse, New Town, 13.xi.56, and 26.ix.57.

3. *Tetranychus urticae* Koch

Tetranychus urticae Koch, 1836, D. Crust. Myr. Arach. Fasc. 1: 10.

Tetranychus urticae is the currently accepted name of the common red spider or two spotted mite. The summer females are yellowish to green in colour with a prominent pair of dark food spots and the hibernating females are orange.

The separation of this species from others in the complex is not easy and is based largely on the shape of the male aedeagus and the cuticular lobes of summer females. The aedeagus has a dorsally

directed bend of almost 90°, the knob is small, with small rather acute anterior and posterior projections, and the surface of the knob is broadly rounded or obtusely angulate. The axis of the knob is approximately parallel with the axis of the shaft.

As described by Boudreaux and Dosse (1963) the dorsal cuticular lobes of the female are mostly large, rounded, with some rather oblong and others narrower with an occasional pointed lobe. Ventrally lobes generally are lacking but there are small lobes between hysterosomal setae I and II.

T. urticae is practically cosmopolitan and has an extremely wide host range. In Tasmania it is an important economic pest on many cultivated plants. Specimens have been examined from the following hosts:—apple, beans, blackcurrant, cucumber, elderberry, hollyhock, hops, maize, passion fruit, pea, pear, strawberry, sweet pea, violet.

4. *Tetranychus rhagodiae* sp. n.

(Figs. 19 and 20)

The aedeagus of the male of *Tetranychus rhagodiae* is somewhat similar in shape to that found in *T. hydrangeae* Pritchard and Baker, *T. merganser* Boudreaux, and *T. kanzawai* Kishida. It differs, however in the angulation of the axis of the knob to the axis of the shaft. The shape of the terminal sensillum of the male palpus of *T. rhagodiae* also differs from that found in the above three species. Females of *T. rhagodiae* are carmine—like those of both *menganser* and *kanzawai*, but differ from either of these species in many other respects.

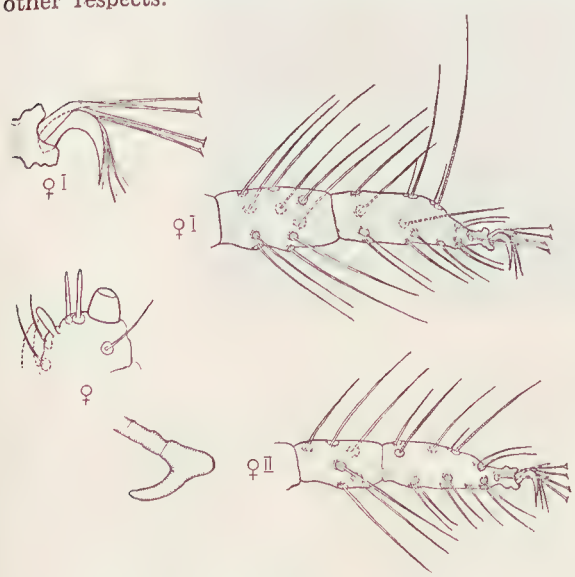

FIG. 19.—*Tetranychus rhagodiae* sp. n. Tibia and Tarsus I and II, empodium I, palp and peritreme—female.

Female. Colour in life deep carmine with dark food spots. Palpus with terminal sensillum stout almost as broad at base as long. Peritreme hooked distally. Tarsus I with four tactile setae distinctly proximad of proximal pair of duplex setae and two tactile and one sensory setae approximately in line

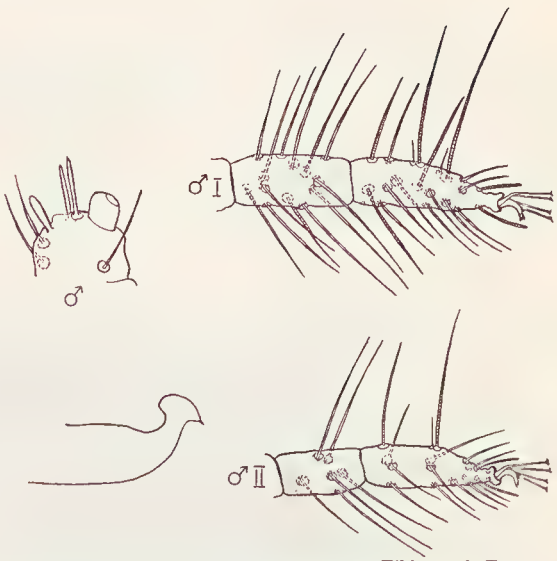

FIG. 20.—*Tetranychus rhagodiae* sp. n. Tibia and Tarsus I and II, palp and aedeagus—male.

with that pair of duplex setae. Tibia I with nine tactile and one sensory setae. Tarsus II with four tactile and one sensory setae proximal to the duplex setae and two tactile setae in line with the duplex setae. Tibia II with six tactile setae. Empodium lacking mediodorsal claw. Transverse striae between third pair of dorsocentral hysterosomal setae and between inner sacral setae. Cuticular lobes on dorsal striae of feeding females generally pointed with fairly wide space between their bases, but becoming more rounded anteriorly. No lobes on medioventral striae but some obscure lobes laterad of second pair of ventral hysterosomal setae. Length of body 378μ greatest width 293μ.

Male. Palpus with terminal sensillum stout almost as broad as long. Tarsus I with four tactile and two sensory setae proximad of proximal pair of duplex setae and one sensory seta in line with that pair of duplex setae. Tibia I with nine tactile and four sensory setae. Empodium I with proximoventral spurs tridigitate, mediodorsal claw very tiny. Tarsus II with three tactile and one sensory setae distinctly proximal to duplex setae and three tactile setae in line with duplex setae. Tibia II with six tactile setae. Empodium II similar to empodium I. Empodium III and IV with proximoventral hairs. Idiosoma with dorsal setae long slender and pubescent. Aedeagus with distal knob moderately large and with dorsal margin of the knob rounded. Axis of knob forming an angle with axis of shaft, knob with rounded anterior projection and acute posterior projection. Length of body 315μ, greatest width 198μ.

Holotype. Male, on *Rhagodia billardieri* R. Br., Cremorne, 10.vi.63, in Australian National Insect Collection, Canberra, A.C.T.

Paratypes. Eighteen males, twenty-six females, same data as holotype, in Australian National Insect Collection, Canberra, A.C.T., South Australian Museum, Adelaide, S.A., and Department of Agriculture, Hobart, Tasmania.

ACKNOWLEDGEMENTS

The assistance given by members of the staff of the Entomology Division—particularly Messrs. N. M. Hudson and K. A. Pickett—in collecting plants from various areas of the State is greatly appreciated.

Mr. D. Macfarlane, Commonwealth Institute of Entomology, London, kindly provided specimens of mites collected by Hirst in 1920.

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Plate I.—*Schizonobia sycophanta* Wom. Peritreme, female.

NOTES ON SPECIES OF ACTAECIA DANA (ISOPODA, ONISCOIDEA) FROM TASMANIA AND NEW ZEALAND

By

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ABSTRACT

A Tasmanian species, which was described in an earlier paper but wrongly assigned there to *Actaecia euchroa* Dana, is named as *Actaecia thomsoni*, n. sp. Differences between *A. euchroa* and *A. thomsoni* are listed. The presence of pseudotracheae in the pleopoda of *A. thomsoni*, and of *A. pallida* Nicholls and Barnes, is confirmed. Variations in the colour of specimens of *A. euchroa* from New Zealand are noted.

INTRODUCTION

In a study of Tasmanian Oniscoidea (Green, 1961) descriptions of two species of genus *Actaecia* Dana, 1853, were published under the names of *A. euchroa* Dana, 1853, and *A. pallida* Nicholls and Barnes, 1927. A subsequent paper on *Actaecia* by Vandel (1964) has shown the need for amendments to these accounts.

Presence of pseudotracheae

The generic diagnosis of *Actaecia* quoted in my paper (1961, p. 295) claimed that, in this genus, the pleopods do not contain pseudotracheae, and no further mention of these structures was made in descriptions of species. Vandel (1964, p. 170, fig. 4) demonstrated the presence of pseudotracheae in the exopodites of all five pairs of pleopods in specimens of *A. euchroa* from New Zealand, and claimed that this feature is characteristic for the genus as a whole. The Tasmanian material on which my descriptions were based, i.e., that of "*A. euchroa*" from Eaglehawk Neck and *A. pallida* from Hawley, was therefore re-examined for evidence of these structures which I had previously overlooked. In both species there are, in fact, pseudotracheae present in the exopodites of all five pairs of pleopods, in both sexes.

Family ACTAECIIDAE

In my study of Tasmanian Oniscoidea, genus *Actaecia* was placed, with genus *Deto* Guérin, 1836, in family Scyphacidae. This position has now been revised, as Vandel (1964, p. 172) has transferred *Actaecia* to a separate family, Actaeciidae, principally because of the presence of pseudotracheae in its pleopods.

Actaecia pallida Nicholls and Barnes

Actaecia pallida Nicholls and Barnes, 1927, p. 155, text—fig. 2, pl. 20.

Description

Additions to the account of specimens from Hawley, Tasmania, given by Green, 1961, pp. 301-4, figs. 91-100:—

Pereion.—First epimeron slightly revolute, its lateral border thickened but not cleft. Second epimeron with a shallow, oblique fold which forms a notch in its lateral border. First to 3rd epimera each with a blunt, subquadrangular lobe on ventral surface.

Pleopods.—Exopodites of 1st-5th pleopods each with pseudotracheae located within a thickened band, raised above dorsal surface, towards outer side of exopodite.

Actaecia thomsoni, n. sp.

Actaecia euchroa Thomson, 1893, p. 56, pl. 2, figs. 1-8 (*non* Dana, 1853).
Actaecia euchroa Green, 1961, p. 295, figs. 75-90.

Location of type specimens

Holotype male and allotype female in the Australian Museum, Sydney.

Paratype male and female in the Western Australian Museum, Perth.

Paratype male and female in the Tasmanian Museum, Hobart.

Description

The account given by Green, 1961, pp. 295-301, figs. 75-90, with the following additions:—

Pereion.—First epimeron slightly revolute, its lateral border thickened but not cleft. Second epimeron with lateral border entire. First to 3rd epimera each with a blunt, subquadrangular lobe on ventral surface.

Pleopods.—Exopodites of 1st-5th pleopods each with pseudotracheae located within a thickened band, raised above dorsal surface, towards outer side of exopodite.

Type locality

A sandy beach on the shore of Pirates' Bay, Eaglehawk Neck, Tasmania.

Remarks

When studying specimens of *Actaecia* from Eaglehawk Neck, I decided to follow Thomson (1893, p. 56) in identifying the species concerned as *A. euchroa* Dana, even though I noted differences between my Tasmanian specimens and descriptions of New Zealand examples of *A. euchroa* in the shape of the eyes and the number of ocelli present (1961, p. 300). These differences were further stressed by Vandel (1964, p. 163) who suggested that the Tasmanian form probably belongs to a separate species or sub-species.

A subsequent opportunity to collect material in New Zealand has enabled me to compare New Zealand examples of *A. euchroa* side by side with my specimens from Eaglehawk Neck, a comparison which has confirmed the status of the latter as a separate species. I have chosen to name the new species *A. thomsoni*, after the late Mr. G. M. Thomson of Dunedin, N.Z., who first collected and described it.

The most conspicuous differences between *A. euchroa* and *A. thomsoni* (based on specimens from Moeraki, N.Z., in the case of *A. euchroa*) are listed in the following table:—

A. euchroa Dana.	*A. thomsoni*, n. sp.
Eye crescentic, composed of about 80 ocelli arranged in four subequal rows.	Eye oval, composed of 14 ocelli.
Lobe on ventral surface of 1st epimeron of pereion blunt and subtriangular; lobes on 2nd and 3rd epimera each subquadrangular, with posterior angle acute and produced backwards.	Lobes on ventral surface of 1st-3rd epimera of pereion each subquadrangular, with angles bluntly rounded.
Second epimeron with lateral border cleft.	Second epimeron with lateral border entire.
Third pleuron of pleon subquadrangular, longer than 4th pleuron, and forming part of general outline of body.	Third pleuron of pleon subtriangular, shorter than 4th pleuron, not forming part of general outline of body.
Outer lobe of protopodite of uropod sharply rounded posteriorly, its maximum breadth about equal to breadth of exopodite.	Outer lobe of protopodite of uropod broadly rounded posteriorly, its maximum breadth more than twice breadth of exopodite.

A. thomsoni is distinguished from *A. pallida* by the shape of the 4th and 5th pleura and the uropods (see Green, 1961, p. 295).

Reference to Chilton's (1901, p. 132, pl. 15, fig. 4; pl. 16, fig. 1) description of the one remaining species in the genus, *A. opihensis* Chilton, 1901, shows that *A. thomsoni* is distinguished from this species by the form of the 3rd pleura and the uropods, and of the endopodites of the 1st pleopods in the male.

Actaecia euchroa Dana.

Actaecia euchroa Dana, 1853, p. 735, pl. 48, fig. 6.

Specimens obtained in New Zealand

The following collections were made by the author:—

From Piha, west of Auckland (North Island), on 14.II.1965; enrolled in burrows in sand a little below high tide level; 11 males and 9 females.

From Moeraki, North Otago (South Island), on 14.III.1965; running on sand at edge of incoming tide; 61 males and 31 females.

From Little Papanui Beach, Otago Peninsula (South Island), on 10.VIII.1964; enrolled in burrows in sand a little below high tide level; one male and 2 females.

A comparison of North Island specimens from Piha with South Island specimens from Moeraki revealed no morphological distinction between these animals from different islands.

Variations in colour

In all specimens from Piha, Moeraki and Little Papanui Beach the background colour of the dorsal surface of the body is almost white. However differences occur in the density and colour of the chromatophores, these differences being correlated with the colour of the sand from which the animals were obtained. In each case, the overall impression of colour given by the live animals was the same as that of their background of sand, thus providing them with an excellent camouflage. More detailed information is given in the following table:—

Locality.	Colour of sand.	Density of chromatophores in *A. euchroa*.	Colour of chromatophores in *A. euchroa*.
Piha	Dark grey, almost black.	Chromatophores very numerous and, in some areas, so close as to be almost touching.	Most chromatophores black; a few orange-brown or yellow.
Moeraki	Intermediate between reddish-brown and light grey.	Chromatophores very numerous and, in some areas, so close as to be almost touching.	A majority of black chromatophores, but many orange-brown and yellow ones also present.
Little Papanui Beach	Light grey, whitish.	Chromatophores less numerous and mostly well separated.	Most chromatophores black; a few orange-brown.

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THE ANTHOCYANINS OF EPACRIS IMPRESSA LABILL.

By

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ABSTRACT

Cyanidin-3-xyloside and cyanidin-3-glucoside have been identified as the major anthocyanin pigments in *Epacris impressa* Labill. It has been shown that the colour gradation evident in flowers in natural populations of *E. impressa* is due to parallel quantitative differences in both pigments. Investigation of other parts of the plant has shown that the same two pigments are present though in varying proportion.

INTRODUCTION

Natural populations of *Epacris impressa* show a conspicuous gradation in colour of the corolla, from deep red through pink to pure white. As well as the corolla, the anthers, style, bracts and leaves may each contain a varying amount of red pigment. This gradation in colour intensity could result simply from a quantitative difference in gross pigment content. Alternatively there may be both qualitative and quantitative variation involving two or more separate pigments. A certain degree of patterning is also evident. Thus in pink flowers, in particular, the corolla pigment is not always uniformly distributed. Moreover, there appears to be no obvious correlation of the degree to which the separate parts of the plant may be pigmented.

In this investigation, leaves, bracts, corollas, styles and anthers of *E. impressa* have been separately examined and both qualitative and quantitative differences have been observed. The results are summarized in the table.

IDENTIFICATION OF THE PIGMENTS

In their survey of anthocyanins in the Australian Flora, Gascoigne, Ritchie and White (1948), reported the occurrence of cyanidin-3-monoside in the flowers of five species of *Epacris*, and cyanidin-3-pentoseglycoside in the bracts of a sixth. (*E. impressa* was not examined). The methods used by these workers, the colour and distribution tests of Robinson and Robinson (1932), do not readily permit the definitive identification of the glycoside. Further, these tests generally overlook the possible co-occurence of minor pigments. For these present investigations we have adopted the more sensitive analytical procedures of paper chromatography and spectrophotometry as developed for the anthocyanins by Bate-Smith (1948) and Harborne (1958a, b).

Plants used in this investigation were obtained from two localities, viz. Ridgeway and Cambridge, both near Hobart, and an independent examination was made of the different parts of the plants as listed in the table.

The fresh plant material was soaked in methanol 3% HCl for 3-12 hours to extract the pigment. After filtration, the extract was centrifuged and streaked as a line near one edge onto several sheets of Whatman 3MM chromatography paper. When dry the chromatograms were developed with the upper layer of butan-1-ol:2N HCl (1.1, by volume Twelve to fifteen hours gave adequate development, and in all samples two distinct anthocyanin bands were evident, (E1 and E2 respectively). The papers were air-dried, the bands separately cut out and eluted with methanol:water:acetic acid (70:25:5, by volume, freshly prepared), and the eluates concentrated under vacuum as previously. E1 and E2 were further purified by successivly rechromatographing in (i), 1% HCl and (ii), butan-1-ol:acetic acid:water (100:22:50 by volume, aged three days), until completely homogeneous anthocyanin fractions were obtained. Chromatography of E2 in solvent (ii), revealed the presence of two components in this fraction, viz. E2/a and E2/b, when red corollas were examined. E2/a, however, was present in very small amount, insufficient in fact, to permit of its complete identification. After the final purification, the eluates containing the anthocyanins were evaporated to dryness in vacuo, and stored pending further tests.

For spectrophotometric examination, the pigments were dissolved in methanol:0.01% HCl to give a solution with an optical density of about 1.300 at 530mμ (Harborne 1958b). The spectra of all three pigments were very similar. Each had a maximum absorption at 528-530mμ, with a bathochromic shift of 16-20mμ caused by the addition of $AlCl_3$ (5% solution in ethanol), indicating the presence of free ortho-hydroxyl groups in the B-ring of the anthocyanin. The ratio of the absorbancies at 440mμ and 530mμ was 22%-24%, suggesting that the 5-hydroxyl position (ring A) was free of glycoside in each case. Finally, the absorption spectrum in the U.V. region showed no evidence of the anthocyanins being acylated.

Partial hydrolysis of E1 and E2/b with 1N HCl for 12 minutes at 100° C under xylene, (Harborne 1958a), yielded aglycone only. Thus these pigments were each 3-monosides. The nature of the aglycones was determined after hydrolysis of a sample of each pigment with 5N HCl at 100° C for 2 minutes. The aglycones were extracted with pentan-1-ol and chromatographed in acetic acid conc.HCl:water (30:3:10 by volume), and formic acid:conc.HCl:water (5:2:3 by volume), alongside reference samples of cyanidin (obtained from roses), and delphinidin (obtained my boiling leucodelphinidin from broad bean in dil.HCl). At the same time the Robinson colour tests for distin-

guishing aglycones were applied. These confirmed that each of the *E. impressa* pigments was a cyanidin derivative.

Identification of the sugar engaged in the glycosidic link with the aglycone, was achieved by neutralyzing the hydrolysate after pentan-1-ol extraction, with N,N,di-n-octylmethylamine (10% solution in chloroform), and evaporating the aqueous layer to dryness in vacuo. The sugar residue was then dissolved in the minimum quantity of water and applied as a spot to a sheet of chromatography paper (Whatman No. 1), alongside reference samples of the pure sugars. Chromatograms were developed in (i), ethyl acetate: pyridine:water (2:1:2 by volume), and (ii) ethyl acetate:acetic acid:water (3:1:3 by volume, upper layer). Visualization was achieved by spraying the dried papers with aniline hydrogen phthallate (2.5% solution in water-saturated butan-1-ol), and heating for 5 minutes at 110° C. By this means, the glycosidic moeity of E1 was shown to be xylose, and that of E2/b glucose.

Thus the two principal anthocyanin pigments of *Epacris impressa* have been identified as cyanidin-3-xyloside and cyanidin-3-glucoside respectively. In addition the minor pigment E2/a, has been partially identified as a cyanidin derivative with glycosidic substitution at position 3 only.

DISCUSSION

Estimation of the relative proportion of the two major pigments in the respective plant organs (see table), was made simply by visual comparison of the intensity of the coloured bands on the chromatograms of the extracts.

The conspicuous colour gradation expressed by the corollas of *E. impressa* appears to be a quantitative difference in the total pigment content, as the relative proportion of the two major pigments is the same in both red and pink flowers. However, in other organs although the same two pigments are present, they occur in quite different proportion to the corolla.

The identification of two cyanidin-3-monoside pigments, supports and extends the earlier observation of Gascoigne et al. (1948), in respect of the flower pigments of other *Epacris* species, but no evidence was obtained in these experiments that cyanidin-3-pentose-glycoside occurred in any organ of *E. impressa*. The possibility that the minor pigment, E2/a, may be cyanidin-3-pentoseglycoside has not been overlooked, although the chromatographic behaviour of E2/a makes this appear unlikely.

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Table showing the Distribution of and relative abundance of the Anthocyanin pigments in *Epacris impressa* Labill.

Plant organ	E1 Cyanidin-3-xyloside	E2 Cyanidin-3-E2/a-?. E2/b-glucoside	Notes
Corolla (anthers red)—			
red	+ + + +	+ +	including anther pigments.
pink	+ +	+	including anther pigments.
white	+ + +	+	anther pigment only.
Bracts—			
red	+ + + +	+ +	
" white "	+	indefinite spot	veinal regions coloured.
Styles red	+ + + +	+	Colour intensifies after corolla withers.
Leaves red	+ + +	+	

A PRELIMINARY INVESTIGATION OF THE SYSTEMATICS OF SOME TASMANIAN GALAXIIDAE

By

G. Stokell

(With four plates.)

ABSTRACT

The investigation has revealed no Tasmanian galaxiid identical with any New Zealand form. The fish known hitherto as *Galaxias attenuatus* in Tasmania is shown to be at least subspecifically different from the form bearing this name in New Zealand. The two forms are referred to the species *maculatus* Jenyns on the grounds of page precedence, and are regarded as different subspecies. No fish agreeing with *G. auratus* Johnson and *G. weedoni* Johnston have been found but *G. affinis* Regan appears to be a valid species represented by variants in different waters.

INTRODUCTION

The present investigation is an attempt to clear up some of the confusion that has surrounded the Tasmanian galaxiids for many years. Species that appear to be merely nominal have been listed on equal standing with others that are at least obtainable and recognisable. The confusion has been increased by the practice of proposing new species without putting the systematics of old ones in order. In the present work no new species are created, but efforts are directed towards defining the forms available and investigating their admissibility to recorded species.

MATERIAL

Most of the material used in this investigation was obtained from collectors engaged through newspaper advertisement. Ten specimens came from Lake Solitude, which is a very small lake at an altitude of about 3,100 feet draining into Lake St. Clair by a creek some 3½ miles in length. There were five specimens from Lake Myrtle in the Mersey River drainage basin and five specimens from Cephisus Creek which joins the Narcissus River near Lake St. Clair. Ten specimens of the fish known as *Galaxias truttaceus* were obtained from the mouth of the Tamar River a few feet above sea level, and nine specimens of the species called *Galaxias attenuatus* in Tasmania were obtained from the same locality. The Tasmanian Museum presented six specimens of the fish called *Galaxias attenuatus* which were combined with the nine from the Tamar River to form the group of fifteen recorded in the discussion. The names *truttaceus* and *attenuatus* used in preliminary discussion are queried to indicate their questionable validity.

TERMINOLOGY AND METHODS OF DESCRIPTION

The most important of the specific characters used is the number of vertebrae. In addition to being a basic osteological character it has a particular value in differentiating species on account of the general lack of correlation between it and certain proportional measurements such as the length of the head in relation to the standard length. Contrary to what might be expected the lower vertebral counts usually occur in the lower bodied species and the higher counts in the shorter-bodied ones, but these characters are not constantly associated, and the occasional exceptions increase their diagnostic value. In counting the vertebrae all bones having a socket at each end are counted, the terminal bone or urostyle, which has a socket at only one end, being omitted.

Another character that has proved of considerable value in separating New Zealand species but is unnoted in Tasmanian descriptions is the degree of development of the pyloric caeca. The number of these structures is usually two but in some species caeca are entirely lacking, in others they are short or rudimentary, and between these and species possessing maximum development there exists a full series of intermediates.

The head in standard length ratio is expressed by indicating the number of times the length of the head, measured to the posterior extremity of the opercular flap, is contained in the standard length.

Other proportional measurements, such as the point of insertion of the dorsal and ventral fins, are recorded by indicating the fraction of the standard length at which these structures originate. This permits precise definition and the convenient indication of variation. Most characters are very variable, and an indication of the range of variation in a substantial group is essential to specific definition. The practice of creating species on one or two specimens is to be deprecated, as is the basing of species on juvenile examples. Juveniles may give very different proportional measurements from adults, as most species are subject to differential growth.

The pectoral fin proportion represents the fraction the length of this fin forms of the distance from its base to the origin of the ventral, and the ventral proportion applies to the length of this

fin and the ventral-anal interspace. The length of the paired fins is the length of the longest ray and not the basal length as is used for the vertical fins.

The tail proportion is the fraction the least depth of the tail forms of the distance from the rear of the dorsal fin to the hypural joint, measured parallel with the axis of the fish.

STRUCTURE

Data on six numerical characters and six proportional measurements of the principal groups investigated are presented in the following tables.

TABLE 1

10 specimens of *Galaxias* from Lake Solitude

Character	*Minimum*	*Maximum*	*Average*
Branchiostegals	7	8	7.66
Dorsal rays (branched)	5	8	6.90
Anal rays (branched)	8	9	8.20
Ventral rays (all counted)	6	7	6.50
Pectoral rays (all counted)	13	15	14.22
Vertebrae	57	61	58
Head in standard length	4.08	4.52	4.23
Dorsal fin insertion	.73	.77	.74
Ventral fin insertion	.51	.55	.52
Pectoral fin proportion	.40	.57	.47
Ventral fin proportion	.44	.65	.52
Tail proportion	.44	.53	.51

TABLE 2

15 specimens of the fish called *Galaxias attenuatus* in Tasmania

Character	*Minimum*	*Maximum*	*Average*
Branchiostegals	6	7	6.57
Dorsal rays (branched)	6	8	7.46
Anal rays (branched)	11	13	12
Ventral rays (all counted)	7	8	....
Pectoral rays (all counted)	12	13	12.47
Vertebrae	58	61	59.66
Head in standard length	4.70	5.73	5.16
Dorsal fin insertion	.73	.79	.75
Ventral fin insertion	.46	.54	.48
Pectoral fin proportion	.32	.50	.42
Ventral fin proportion	.34	.44	.39
Tail proportion	.36	.50	.43

TABLE 3

5 specimens of *Galaxias* from Lake Myrtle

Character	*Minimum*	*Maximum*	*Average*
Branchiostegals	7	8	7.25
Dorsal rays (branched)	7	9	7.80
Anal rays (branched)	8	10	8.20
Ventral rays (all counted)	7	7	7
Pectoral rays (all counted)	15	15	15
Vertebrae	59	61	60
Head in standard length	4.45	4.73	4.66
Dorsal fin insertion	.69	.72	.71
Ventral fin insertion	.50	.51	.506
Pectoral fin proportion	.47	.57	.52
Ventral fin proportion	.61	.67	.64
Tail proportion	.38	.45	.42

TABLE 4

10 specimens of the fish called *Galaxias truttaceus*

Character	*Minimum*	*Maximum*	*Average*
Branchiostegals	7	9	7.63
Dorsal rays (branched)	8	10	8.30
Anal rays (branched)	10	11	10.66
Ventral rays (all counted)	6	7	6.95
Pectoral rays (all counted)	14	15	14.14
Vertebrae	60	62	60.60
Head in standard length	4.06	4.75	4.43
Dorsal fin insertion	.70	.74	.72
Ventral fin insertion	.50	.55	.52
Pectoral fin proportion	.40	.55	.51
Ventral fin proportion	.48	.61	.54
Tail proportion	.44	.57	.49

Frequency Tables in the more important meristic characters and a table of minimum, maximum and average values in the head in standard length ratio are given in the following discussion.

TABLE 5

Frequency of occurrence of vertebral counts

Designation	*Number of Specimens*	*Vertebrae*						
		57	58	59	60	61	62	*Average*
Lake Solitude	10	5	3	....	1	1	....	58
G. attenuatus?	15	....	1	5	7	2	....	59.6
Lake Myrtle	4	....	....	1	2	1	....	60
G. truttaceus?	10	....	....	....	5	4	1	60.2

The Lake Solitude group has a definitely lower number than any of the others and on this character must be regarded as distinct.

The character next in importance is the number of branched rays in the anal fin. Taking the groups in the same order the values are as follows.

TABLE 6

Branched rays in anal fin

Designation	Number of Specimens	Branched anal rays 7	8	9	10	11	12	13	Average
Lake Solitude	10	....	8	2	....	....	....	....	8.20
G. attenuatus?	15	....	....	....	....	5	4	6	12.06
Lake Myrtle	5	....	1	2	2	....	....	....	8.20
G. truttaceus?	12	....	....	....	4	8	....	....	10.66

The high counts in the *attenuatus?* group are sufficient to separate the fish composing it from all others recorded. The Solitude group has the lowest average, which appears to be sufficient to separate it from the two intermediate ones.

The number of dorsal rays does not appear to be a very important character but the number of ventral rays shows remarkable variation in one group. In most species of *Galaxias* the number is normally 7 but many show an occasional variation of 1 either way. There are usually 6 branched rays and 1 single one in each fin, which are totalled as 7 for convenience in tabulating. Rudimentary rays of less than half the height of the fin, which sometimes occur, are indicated in the following table by a plus sign after the number of developed rays.

TABLE 7

Number of ventral fin rays

Designation	No. of fins	6	6+	7	7+	8
Lake Solitude	20	7	3	9	1	....
G. attenuatus?	30	....	....	29	....	1
Lake Myrtle	10	....	....	10	....	....
G. truttaceus?	20	1	....	19	....	....

The only group free from variation is the one from Lake Myrtle, and this is too small to justify an assumption of constancy. The frequency of variation in the Solitude group is so high that only three of the ten specimens examined are typical in having 7 rays in each fin. Individual particulars of the ten are: 6-6, 6-6, 6-6 +, 6-7, 6 + -7, 6-7 +, 7-7, 7-7, 7-7. In species of *Galaxias* not normally 7 rayed there are other dominant numbers, 5 in *Galaxias burrowsius* Phillips, and 6 in *Galaxias divergens* Stokell, both of which vary occasionally, but the Solitude fish can be classed only as highly inconstant. Two specimens from a tributary of Lake Augusta, each of which has 58 vertebrae, show abnormal variation in the number of ventral rays, one having 7-7 and the other 6-6. While the character of high variation in the number of ventral rays requires taxonomic recognition it seems most appropriate as a subspecific distinction.

The number of branchiostegals appears to be of little importance except in separating *attenuatus?* which has a range of 6-7. In the others it is 7-8 or 7-9.

The most important of the proportional measurements in the head in standard length ratio, particulars of which are tabulated below.

TABLE 8

Head in standard length ratio

Designation	Number of Specimens	Minimum	Maximum	Average
Lake Solitude	10	4.08	4.52	4.23
G. attenuatus?	15	4.70	5.73	5.19
Lake Myrtle	5	4.45	4.73	4.66
G. truttaceus?	10	4.06	4.75	4.43

The only significant difference is shown by the *attenuatus?* group, which has a definitely higher ratio than any other in the table.

Of the characters that are not tabulated the form of the pyloric caeca carries the greatest interest. These structures differ considerably between some groups, and are much more variable within groups than is usual in New Zealand. Tasmanian caeca are usually more tapered than New Zealand ones. The Solitude group shows about normal development but the length varies considerably. In the *attenuatus?* group the caeca vary from short definite protuberances to mere wide bulges. The caeca are very variable in the *truttaceus?* group and sometimes absent. When present they are usually short and as wide at the base as high. Five large specimens from Cephisus Creek have rather unusual development. The caeca differ considerably in length and vary in shape from moderately tapered to almost cylindrical. They are not constant in number, three specimens having two caeca and two having three. These specimens are not tabulated as they show little difference in the characters listed from the the Solitude group. They have more finely subdivided rays in the anal fin and are the largest Tasmanian *Galaxias* observed, the largest specimen being 207 millimeters in total length.

The arrangement of large open pores on the head is a character of some value. It is usual for one pore to occur on each side of each anterior nostril, one well in from each posterior nostril with the posterior edge of the pore about level with the anterior edge of the nostril, a pair in the interorbital space in line with the second nostril pores and at .25-.50 of the eye diameter from the front of the eye, a pair in the interorbital space about level with the rear of the eyes, and one pore

behind the upper extremity of each eye. On the side of the head there are usually two pores about level with the centre of the eye, one of them slightly higher than the extremity of the maxillary and the other slightly lower, the lower one usually behind the other. There are also three or four on the posterior of the cheek and one or two on its lower edge. There are invariably two pores above each upper lip and two below each lower lip.

The Solitude group is variable in the position of the second nostril pore and usually has it much farther forward. The most usual arrangement is for the pore to be about one diameter forward of the nostril but it may extend forward as much as two diameters and in the posterior extreme is just forward of the nostril. The first interorbital pair is at about .2-.3 of the eye diameter from the anterior of the eye and the second interobrital pair is at about .7-.8. The postorbital pores are forward of the posterior extremity of the eyes and almost level with the posterior interorbital pair. The two pores behind the posterior extremity of the maxillary are behind the perpendicular from the rear of the eyes.

The lateral teeth in the mandible are more or less enlarged in the Lake Solitude, Lake Myrtle and *truttaceus?* groups, but are equal in the *attenuatus?* group.

Entopterygoidal teeth are about normal in all groups, and range from four to seven on each bone.

Minute pharyngeal teeth occur in all forms investigated. So far as the writer is aware pharyngeal teeth have not been recorded in *Galaxias,* but they are noted in a New Zealand paper which may not be published for a considerable time.

The gill rakers are short in the Solitude group and usually of moderate length in the others.

The origin of the anal fin is about perpendicular from the origin of the dorsal fin in the *attenuatus?* group and below the fifth-seventh ray (all counted) in the others.

NOMENCLATURE

The principal evidence on the identity of the upland species consists of a specimen of *G. auratus* Johnston and a specimen of *G. weedoni* Johnston, presented to the British Museum by Johnston himself, and three specimens of *G. affinis* Regan which were used by Regan in the Museum when describing the species. Through the kindness of Dr. P. H. Greenwood, head of the Department of Fishes in the institution, radiographs of all these specimens have been taken and presented to the writer. The two of Johnston's specimens and the best of Regan's are reproduced in Plate 1. The print of *G. auratus* shows 55 vertebrae definitely, but that of *G. weedoni* is less certain. At the posterior extremity several bones are disturbed and not clearly shown, but counting the neural spines in this short section and estimating the intervals the number appears to be 55 also. It seems questionable if these two nominal species are distinct. As 57 is the lowest count recorded in the tables none of the present forms can be referred to *auratus* or *weedoni.* The best specimen of *G. affinis* has 57 vertebrae and the other two appear to have 57 and 59, which come within the range of the Lake Solitude and Cephisus Creek forms. These two forms appear to be referable to *G. affinis,* and are left in the position of possible variants of this species. The present need is for a redefinition of *affinis* based on a workable group from Lake St. Clair.

The fish known as *Galaxias attenuatus* in Tasmania differs materially from the form bearing this name in New Zealand. The most important difference is in the number of vertebrae, which ranges from 58 to 61 in Tasmanian specimens and from 61 to 63 in New Zealand ones. In twenty New Zealand specimens dissected no individual with less than 61 was found, the frequency distribution being nine with 61, eight with 62 and three with 63. Fifteen Tasmanian specimens gave counts of one with 58, five with 59, seven with 60 and two with 61. The character next in importance is the number of branched rays in the anal fin, which does not range below 13 in the New Zealand fish or above 13 in the Tasmanian one. The frequencies of the group of twenty New Zealand specimens are eight with 13, four with 14, five with 15 and three with 16. Fifteen Tasmanian specimens have five with 11, five with 12 and five with 13. The branched rays in the dorsal fin number 8-10 in the New Zealand specimens and 6-8 in the Tasmanian ones. These differences might justify specific separation of the New Zealand and Tasmanian forms now referred to *attenuatus* if it were not for the existence of a somewhat intermediate form in South America. Three specimens from Chile, where the fish is known as *G. maculatus* have 61-62-62 vertebrae, 12-13-13 branched rays in the anal fin and 6-8-8 in the dorsal. The Chilean form therefore agrees best with the New Zealand one in the number of vertebrae and with the Tasmanian one in the number of anal and dorsal rays.

The first record of these fishes was made by Jenyns who, in 1842, described three species collected during the Voyage of the Beagle in 1832-36. He appears to have been unaware of the establishment of *Galaxias* Cuvier 1817 as he proposed for his new species the genus *Mesites* which he defined almost similarly. The first species *Mesites maculatus* was described on page 119 of the publication and was recorded from Hardy Peninsula Tierra del Fuego and Santa Cruz Patagonia. *Mesites alpinus* which was described on page 121, was recorded from fresh water lakes in Hardy Peninsula, Tierra del Fuego and *Mesites attenuatus* described on the same page from Bay of Islands New Zealand. Types of all species were established in the museum of the University of Cambridge and were handed over to the British Museum (Natural History) in 1917. Some years ago the types of *attenuatus* and *maculatus* were x-rayed for the writer in order to determine the number of vertebrae, the counts recorded being 64 for the type of *attenuatus,* 64 for the type of *maculatus* and 61 and 63 for co-types of *maculatus.* These counts would appear to have included the urostyle, as no record of 64 has ever been made from New Zealand specimens by the present writer's method of counting. If this is so one of the specimens of *maculatus* comes below the minimum in the New Zealand fish.

Frequency Table of Vertebral Counts

Locality	Number of Specimens	Number of Vertebrae					
		58	59	60	61	62	63
New Zealand	20	....	....	....	9	8	3
Tasmania	15	1	5	7	2	....	....
Chile	3	....	....	....	1	2	....

All Jenyns' descriptions were based on juvenile examples from two inches to about two and a half inches in total length. In view of the differential growth prevalent in these fishes during the transition from the juvenile stage to the adult stage the proportional measurements given have little definitive value. Colouration, to which much importance was attached, also shows a considerable change at this stage. When the New Zealand fish come in from the sea they are unpigmented except for the eyes and vertebral column, the normal colour pattern commencing to develop after a short residence in fresh water. The most important character recorded in the original descriptions is the number of anal fin rays which is given as 15-16 in *maculatus*, 16 in *alpinus* and 17 in *attenuatus*. The figures are not sufficiently different for specific separation, and the three forms as described cannot be regarded as distinct.

Cuvier and Valenciennes (1846) recognised these fishes as belonging to the genus *Galaxias* in which they placed them, thus reducing *Mesites* to a synonym. Günther (1866) who followed this classification recorded *attenuatus* from New Zealand, Tasmania, South America and Falkland Islands; and Regan (1905) added the mainland of Australia to the localities of occurrence. The Australian fish is not separable from the Tasmanian one. In a group of twenty specimens from the mouth of the Lang Lang Creek Victoria, the vertebral counts are—one specimen with 58, two with 59, thirteen with 60, three with 61 and one with 63. The individual with 63 appears to be an abnormal specimen, the more so on account of the absence of any with 62. The vertebrae of another group of Victorian specimens, most of them from the same Lang Lang Creek collection, were counted as a check. There was no specimen with more than 61 vertebrae in the group. The occurrences are ten specimens with 59, seven with 60 and three with 61. The average for this Victorian group is 59.65, that for the Tasmanian group is 59.60, and that for the first Victorian group is 60.1.

There is no difference of consequence in the number of branched rays in the anal fin, the range being 11-13 in each and the averages 12.18 in the Tasmanian group and 12.27 in the Australian one.

A consideration of the status of the three forms leads to the conclusion that the differences between them are not sufficient for specific separation. The Tasmanian and Australian form is the most distinct, and if it and the New Zealand one were all that existed two species would be justified, but the South American form agrees with the one in the anal and dorsal ray counts and with the other in the number of vertebrae. Specific union of the three seems called for, and the recognition of each as a subspecies would provide the distinction between them that is so necessary. Under this arrangement the specific name to be used would be *maculatus* on the grounds of page precedence. The South American form, to which this name was applied would repeat the specific name, becoming *Galaxias maculatus maculatus* Jenyns, the New Zealand one would be *Galaxias maculatus attenuatus* Jenyns, and the Tasmanian and Australian one, which was not dealt with by Jenyns, would take as a subsepecific name the earliest one applied specifically by another author if such should exist. Many nominal species have been proposed from Australia some of which have been regarded as synonyms of *attenuatus*, but even if they could be identified from the scanty data furnished most of them would not be available now. *G. krefft* Günther (1866) has never been recognised and is now a *nomen oblitum*. *G. punctatus* Günther (1886), *G. waterhousii* Krefft (1867), *G. cylindricus* Castelnau (1872), *G. delicatulus* Castelnau (1872), *G. nebulosus* Macleay (1881) and *G. obtusus* Klunzinger (1872) appear to be in the same category. They were not included as valid species in the list of Regan (1905) and McCulloch (1929), in consequence of which they are judged to be lapsed names. *G. versicolor* Castelnau (1872) was included in both Regan's and McCulloch's lists and would still be available. It is described as having a total of 12 rays in the anal fin which disqualifies it as a species to which the Australian form known as *attenuatus* could be referred.

G. amaenus Castelnau (1872) which also has been kept alive by inclusion in Regan's and McCulloch's lists is described as having a head in total length of $4\frac{1}{3}$. This indicates a much longer head than ever occurs in the fish known as *attenuatus* in Australia. These species are very poorly described, and the account of *versicolor*, at least, is based on a single specimen. *G. scriba* Cuvier and Valenciennes (1846) may have been saved from lapsing by Whitley's (1933) use of the name in the trinominal *Austrocobitis attenuatus scriba* Cuvier and Valenciennes, but the matter is of little consequence, as the length of the head and the form of the caudal fin recorded in the description of *scriba* differ substantially from those of the Australian and Tasmanian fish commonly regarded as *attenuatus*.

There does not appear to be any name to which the present fish can be referred, and while it is desirable in the interests of general taxonomy that the standing of the few still remaining names should be investigated, if this is possible, it seems doubtful if any could be removed from the status of *species dubi*.

Under the circumstances it seems fitting to propose a new subspecific name indicative of the uncertainty that has existed, and to present a description sufficient to distinguish the fish from the New Zealand form for which it has been mistaken. A fuller investigation of South American specimens is desirable and if this should

show the necessity for full specific separation the present subspecific names would become specific ones.

GALAXIAS MACULATUS Subspecies *IGNOTUS*

Galaxias attenuatus Johnston. *Pap. and Pro. Roy. Soc. Tasmania* 1886 p. 130.

B. 5-7. D.III-V 6-8. A.III-IV 11-13. V. 7-8 (usually 7). P. 12-13. vertebrae 58-61 (average 59.66).

Jaws about equal, teeth in jaws about equal. Entopterygoidal teeth well developed, 4-7 on each bone. Gill rakers moderately developed, pyloric caeca varying from wide bulges to short definite protuberances, rather stout and round ended.

Head 4.70-5.73 in standard length, maxillary extending from scarcely to the perpendicular from the anterior of the eye to slightly past this point, diameter of eye 0.24-0.25 of the length of the head.

The dorsal surface of the head has one large open pore on each side of each anterior nostril, one well in from each posterior nostril, the longitudinal position varying from the posterior edge of the pore being level with the anterior edge of the nostril to the middle of the pore being level with the nostril edge. A pair in interorbital space at 0.25-0.30 of the eye diameter from the anterior of the eye, a pair in the interorbital space at about 0.75 of the eye diameter from the anterior of the eye, one pore above each eye slightly forward of the posterior interorbital pair. One pore on side of head behind extremity of maxillary and below about centre of eye, one lower, may be forward of or behind the suborbital pore, three on posterior edge of cheek, two on lower edge of cheek. Two above each upper jaw and two below each lower jaw.

Dorsal fin originating at 0.73-0.79 of the standard length, ventrals at 0.46-0.54 of same. Pectoral fins extending 0.32-0.50 of the distance from their origin to origin of ventrals, ventrals extending 0.34-0.43 of the distance from their origin to origin of anal, anal originating below origin of dorsal, branched rays of anal divided into two. Least depth of tail 0.36-0.50 of the distance from the rear of dorsal to hypural joint. Caudal fin concave with slightly rounded lobes.

Colour (in spirits) Ground colour and lower surface pale, sides with numerous narrow transverse bands of a greenish grey sometimes breaking up into a general mottling.

Maximum total length observed 108 mm.
Recorded locality lower Tamar River.

Differs from *Galaxias maculatus attenuatus* of New Zealand in having less vertebrae, less anal rays, less dorsal rays and a lower head in standard length ratio.

Tamania and mainland of Australia.

The fish from Lake Myrtle cannot be associated with any of the other groups recorded. It has 59-61 vertebrae, and in this comes very close to the species just described, but it differs from this species in having less branched rays in the anal fin and longer pectoral fins, ventral fins and head. The first and second of these differences are absolute but the third and fourth are subject to a small overlap in values. The Lake Myrtle fish differs from other Tasmanian forms discussed in the disposition of large open pores on the head. The second nostril pore is about two diameters ahead of the nostril and the first interorbital pair is not actually between the eyes but about level with their anterior edge. The second interorbital pair is nearly as far back as the rear of the eyes and the level with the postorbital pores. Other pores are about normal. The pyloric caeca are very variable. Some of them come nearer to the form occurring in New Zealand species than those of other Tasmanian species do, being long and cylindrical while others are slightly or definitely tapered.

The Lake Myrtle fish appears to be new, but it would be improper to name it on the small group available, and until something like order has been brought to the Tasmanian species. This water is in the Mersey drainage basin, the only species recorded from which is *G. weedoni*. The low number of vertebrae in *weedoni* excludes the present fish from this species.

The name *truttaceus*, which is universally applied to the common black-spotted species of Tasmania and Victoria, is of very doubtful validity. It was first used by Cuvier (1817) in a footnote to the definition of the genus *Galaxias*, but no description of *truttaceus* was given and no locality indicated. The definition is as follows:—

"Les *Galaxies* (*Galaxias* Cuv.)

Out le corps sans écailles apparentes, la bouche peu fendone, des dentes pointues et médiocres aux palatines et aux deaux machoires, enfin quelques fortes dentes crochues sour la langue.

Les cotes de leur tete offrent des pores, et leur dorsale répond a l'anale, comme des les brochets, dont ils ont aussi les intestines (1).".

The footnote at the bottom of the page is:—

"(1) *Esox truttaceus* Cuv. espec nouvelle, ou peut-etre L'es. *argenteus* Forst? "

In the later editions of Cuvier the definition is the same but the footnote is "*Esox truttaceus* Cuv. *Esox alepidotus* Forst."

The first mention of a fish that can be recognised as a galaxiid was made by G. Forster (1777) in his account of Captain Cook's stay at Dusky Bay, New Zealand in 1773. He records the discovery of a bushed lake, the only inhabitant of which appeared to be a small species of fish (Esox) without scales resembling a little trout, brown in colour mottled with yellowish spots in the shape of some ancient Asiatic characters. In 1789 Gmelin, the compiler of the 13th edition of Systema Naturae, gave a latinised description based on G. Forster's account of the Dusky Bay fish but transposed a name (*Esox argenteus*) proposed by G. Forster for a very different fish taken from the sea at Tanna Island, on the assumption that they were identical. Gmelin's account is given below.

p. 1393 (Esox).

argenteus. 12. Es. fuscus litteris flavicantibus pictus. G. Forster *it. circa orb. I. p.* 159. *Habitat in* novae Seelandiae, *aliarumque* oceani pacifici *insularum aquis dulcibus, exilis, truttae similis.*

In 1801 Bloch and Schneider published J. R. Forster's account of the fishes taken on Captain Cook's voyages, and recorded the yellow-spotted species from Dusky Bay as *Esox alepidotus*, which was J. R. Forster's manuscript name. These descriptions were published many years before Cuvier defined his genus, and no description of the Tasmanian fish appears to have been published in the interim. The yellow or golden markings recorded on the New Zealand fish constitute the principal evidence of the species on which the genus was founded. Their resemblance to a galaxy suggests the reason for the name *Galaxias*, which cannot be conceived to have been inspired by a contemplation of the black-spotted fish in Tasmania. Cuvier and Valenciennes (1846), actually Valenciennes who wrote of Cuvier in the third person, asserted that the genus was based on the Tasmanian fish, and applied the name *truttaceus* to this species, but made no attempt to explain the name *Galaxias* or Cuvier's alleged ignorance of the New Zealand fish until the Tasmanian one was obtained.

The application of the name *truttaceus* to the Tasmanian fish appears to be a misidentification of a type species, and a new name or the reinstatement of a synonym to be necessary. *Galaxias ocellatus* McCoy (1867) was recognised by Castelnau (1872) but does not appear to have been used since, and must be classed as a *nomen oblitum*. *Galaxias scopus* Scott (1935) appears to be the next possible synonym. It was proposed for a fish regarded as distinct from the black-spotted species commonly called *truttaceus*, but was based on only two specimens. The principal distinction recorded was the point of origin of the anal fin, which was described as below or slightly behind the origin of the dorsal fin. Tasmanian specimens of the black-spotted species in the present collection have the first anal ray below the 3rd-7th dorsal ray. In an x-ray of the holotype of *scopus*, kindly furnished by the Queen Victoria Museum, the first anal ray appears to the writer to be below the second or third ray of the dorsal. A specimen from Flinders Island which is close to Clark Island, the type locality of *scopus*, has the first anal ray below the third dorsal ray. This specimen has 60 vertebrae and comes well within the range of the black-spotted species of Tasmania in other important characters. The x-ray of the type of *scopus* is not clear enough for a definite count of vertebrae, but the number appears to be about 60. It would thus appear that the species *scopus* comprehends the common black-spoted fish of Tasmania and Victoria, and that this is the valid name for the species. A description based on the group of ten specimens from the lower Tamar River and its tributaries is given below.

GALAXIAS SCOPUS Scott

Galaxias truttaecus Valenciennes in Cuv. and Val. Hist. Nat. Poiss. 1846.

Galaxias truttaceus Johnston. Pap. and Pro. Roy. Soc. Tasmania. 1886.

Galaxias truttaceus Regan. Pro. Zool. Soc. London. 1905.

Galaxias truttaceus Scott. Pap. and Pro. Roy. Soc. Tasmania. 1935.

Galaxias scopus Scott. Pap. and Pro. Roy. Soc. Tasmania. 1935.

B. 7-9. D. iii-v 8-10. A. iii-v 10-11. P. 14-15. V. 6-7 (usually 7) vertebrae 60-62.

The lower jaw usually very slightly the longer. Lateral teeth in lower jaw usually slightly enlarged, entopterygoidal teeth strong, 5-7 on each bone. Gill rakers short to moderate in length and usually rather stout. Pyloric caeca very variable and sometimes absent. When present usually short and as wide at the base as high.

Head 4.06-4.75 in standard length, maxillary extending 0.2-0.4 of eye diameter past perpendicular from anterior of eye.

Pores on dorsal surface of head about normal, the posterior interorbital pair at about 0.7 of the eye diameter from anterior of eye, the post orbital pores slightly forward of these. Two behind extremity of the maxillary, the lower usually slightly forward of the upper.

Dorsal fin originating at 0.70-0.74 of the standard length, ventral at 0.50-0.55 of same. Pectoral fins extending 0.40-0.55 of the distance from their origin to origin of ventrals, ventrals extending 0.48-0.61 of the distance from their origin to origin of anal, anal originating below 3rd-7th dorsal ray, branched rays of anal divided into two. Least depth of tail 0.44-0.57 of the distance from the rear of dorsal fin to hypural joint. Caudal fin moderately concave with well rounded lobes.

Colour (in formalin) Ground colour and lower surface varying from pale to dusky. Sides with round distinct black spots over trunk and tail, ventral, dorsal and anal fins may have distinct black tips or may be pale throughout.

Maximum total length observed 142 mm.

Localities: Lower Tamar River and its tributaries, Flinders Island and Victoria.

ACKNOWLEDGMENTS

Thanks are expressed to the British Museum for radiographs of *G. auratus, G. weedoni* and *G. affinis*, to the Queen Victoria Museum for a radiograph of the type of *G. scopus* and to the Tasmanian Museum for seven specimens of the fish hitherto regarded as *G. attenuatus*.

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Plate I.—Radiograph of *Galaxias auratus*. (Per British Museum.)

Plate II.—Radiograph of *Galaxias weedoni*. (Per British Museum.)

Plate III.—Radiograph of *Galaxias affinis*. (Per British Museum.)

Plate IV.—Stomach with three pyloric caeca.

AN ACCOUNT OF FOOD AND DRINK IN TASMANIA. 1800-1900.

"SLIPPERY BOB AND BLOW MY SKULL."

By

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ABSTRACT

The consumption of food in Tasmania is traced from historical accounts between 1800 and 1900. The consumption patterns were apparently greatly influenced by the historical and economic development of the Colony. The differences between the diet of the free settlers and the captive part of the population are described.

INTRODUCTION

The problem of what determines food habits and how they can be changed is of concern to the health of mankind.

These food habits have been built up in every country over the years, as the result of natural movements within its society.

If information can be collected about past food trends it may be possible to find the causes of change and so predict the pattern of change in coming years. With that in mind, an attempt was made to collect data concerning the changing food habits of Tasmanians between 1800 and 1900. As will be noticed, this information is only scantily available for Tasmania.

Historians can make a great contribution by recording this type of data, particularly concerning people who have moved into new conditions with prevailing food habits different from their own. Historians will then help social and natural scientists in their efforts to devise methods and techniques which will induce food habit changes which fit in with past and existing currents of change.

BEFORE SETTLEMENT

For the aborigines, Tasmania was virtually one big butcher's shop. When the Tasmanian aborigine picked up his weapons, all fur and feather creatures were his target. These included the big Forester kangaroo, platypus, bandicoot, spiny anteater; even Tasmanian devils were destined for his cooking fire. The women were delegated to catch the possums, seals and fish, the pick of the hunt being for the male aboriginal. This diet accustomed their palates to a variety of flavours, possums giving a strong eucalyptus flavour, the kangaroo and wallaby rats and the bandicoots being earthy in taste, whereas the platypus had a muddy flavour and the spiny anteater or native porcupine tasted like pork. The Tasmanian devil, being a scavenger, would be strong meat indeed.

Both land and water birds and their eggs were in plentiful supply, those of the emus, though smaller than the mainland kind, being the biggest. Roast duck of various types was on the menu—the black and mountain duck, the grey teal, quail, and heron were all available. Hawks, falcons and kestrels fell to their weapons. Cockatoos and parrots also were brought down.

Tiger snakes and copperheads, thick as a man's arm, went on the cooking fires, as well as goannas or blue-tongued lizards.

With crayfish the price they are today, we can only envy the plentiful supplies of giant freshwater crays which weighed up to 8 lb., and measured 2 feet. The South Esk and its tributaries yielded mussels up to 4 inches across. Grubs were another delicacy, particularly the large white Wattle Goat Moth, also the fat creamy grubs of the Longicorn or Banksia beetles.

Sweets were practically off the menu. Manna, which tastes a bit like icing sugar, was occasionally obtained from the twigs of the White Manna Gums. The amber-coloured gum, particularly that from the Black Wattles, was also sought for its sweetness. Vegetables were very scarce. "Yams' were dug with digging sticks. These "yams" were the small tubers that form on the root of the many species of the native orchids. Roots of the bracken fern were also eaten. These were dug up and pounded and steeped in water. The white powdery substance was mixed into paste and baked on hot stones. The best thing was to find a loaf of Blackfellows Bread. This was an underground fungus, with a hard crust, which may weigh several pounds. The inside is white and cellular with the texture of bread, with an acid rice pudding flavour. In autumn mushrooms were in plentiful supply.

1804-1808

Van Diemen's Land settlements were populated at first by nothing but convicts, with their guards and some officials. There were hardly any free settlers. Provisions were brought in by ships, and game captured in Van Diemen's Land made a valuable contribution to the diet. Reverend Knopwood, the first Chaplain in Tasmania, told in his diary about the food he ate. He recorded that he killed some quails and kangaroos and when on October 10, 1804, Knopwood dined with his friends, the "piece de resistance" was emu, which was found "very excellent". On another occasion

he dined with his military friends on fish, kangaroo soup, roast saddle of kid, two fowls pellewed with rice, bacon and roast pig.

Knopwood shot a large 20-lb. conger eel and caught crayfish. In November, 1804, 17 black swans were killed by Bowden and his party, while another group killed 22. It therefore seemed very wise of the Governor to make the first game law in 1804, prohibiting black swans to be molested during the breeding season, because he feared that such a valuable source of fresh food might be exterminated.

Oysters were found in bountiful quantities, and oyster shells, being so plentiful, could be sold for the official price of threepence per bushel and were used for building purposes.

Although little food was grown, a dish of green peas was presented to the Governor on October 19, 1804. In York Town more was planted; after only 10 weeks of settlement, vegetables such as peas, french beans, potatoes and turnips, were available.

The following prices for food were fixed by General Order of June 22nd, 1804:—

"Salt Beef	9d. per lb.
Salt Pork	1/- per lb.
Kangaroo	8d. per lb.
Flour	1/- per lb."

As mechanics earned 3/6 per 10-hour day, and labourers 2/6, they could buy with their money 2 lb. beef and 2 lb. flour or 1 lb. pork and 1½ lb. flour. However, at the end of 1805, provisions became scarce. In April, 1805, the weekly ration was reduced to 3½ lb. beef, 6 lb. flour, 6 lb. wheat and 6 oz. sugar, but in August the allowance had to be clipped to 2 lb. 10 oz. pork, 2 lb. flour, 2 lb. wheat and 2 lb. meal, and to Knopwood's distress there was "not a drop of spirit in the colony". As he was interested in food, and looked after his garden well, he paid £3 10s. for one bushel of seed potatoes. Prices went up and up, and on September 27, 1805, the following prices were paid: biscuits 4/- per lb.; meal 8/6 per lb., maize 2/3 lb., sugar 5/- per lb., rice 2/6 per lb., kangaroo 1/- per lb., tobacco "not fit to be made use of, 2/6 per inch". On October 4, potatoes were 2/- per lb., and flour 6/- per lb. On October 13, he reported "my poor pigeons are almost dead for want of provisions—only 4 remaining out of 16". The entry for November 28, 1805, is: "Meat 3/6 per lb., coarse meal 9/-, Indian corn 7/- per lb.; very bad and little can be obtained. No work is done—the poor people go out fishing". Misery continued, Lieutenant Lord bought the last pound of tea and paid six guineas. Sometimes the store was empty of provisions "Not an ounce of meal, wheat or anything to be served to the military or prisoners—none in the store for anyone. No ship arrived".

The population of Hobart Town was only small at that time, merely 471, and at Launceston 301. On April 28, 1807, Collins sent for the bakers and as a result the price of a 2-lb. loaf of bread was reduced from 5/- to 4/-. In 1808, Lt. Govenor Collins reported that he had to receive kangaroo into the store and made a regular issue of kangaroo and emu meat to all in the settlement at Hobart Town.

Similar reports were received from Port Dalrymple. Botany Bay Greens (Atriplex) a plant related to saltbush and Pig's Face (Mesembryanthemum) were collected from the seashore, cooked and eaten. Crap or refuse of the blubber of whales washed up on the shore and from which the oil had been removed was also eaten. When finally one of the ships came in, Knopwood was delighted to receive 228 gallons of spirits from it. He wrote that in the afternoon "he felt so unwell that he could not dine at Mr. Bowden's'. He was a frolicksome parson, who loved his social engagements, hunting, fishing, eating and drinking.

1808-1824

When the news of a possible occupation by the French reached England, an order was given to transfer all free settlers from Norfolk Island to Van Diemens Land. Two hundred of them, all farmers, millers and gardeners came to Tasmania and received small grants around New Norfolk. These were the first small free holders in Tasmania. To encourage prisoners and if possible to accustom them to industrious habits, small grants were given them. Land about Hobart, Sorell Town, the Coal River, Bagdad and Tea Tree Brush, New Norfolk at the south side, Norfolk Plains and Pattersons Plains was allocated.

Moreover, the land near the settlements was cleared and cultivated by convict labour. As a result, Hobart Town and Launceston became more self-supporting.

In 1814 immigration of free settlers received a boost. Free grants of land were promised in proportion to the value of the capital brought in to Van Diemen's Land, that is to say, that for every £1,000 of capital, new settlers could get a grant of 1,000 acres. Another bonus was the possibility of getting assigned convict servants to do the farm work for nothing or for the cost of their food. The next 20 years saw many settlers snapping up land in the plains and open forest country in east V.D.L., so much so that the area round Pittwater became the Colony's and Australia's granary. As wheat was reaped by sickle and threshed with a flail, all hand work, the free-of-charge convict labour made this possible. The development of the land for stock and crops also improved conditions considerably.

Another profitable venture was the whaling industry. Within 20 years the black whales in the estuary of the Derwent were almost extinct, but the great sperm whales remained to be chased in the open ocean. Thousands of seals were caught and slaughtered for their skins and blubber. Generally speaking, however, growth of the Colony was not spectacular until the 1820's.

1824-1840

The new Governor, Arthur, was not interested in free enterprise and development of V.D.L. His interest was to shape the Colony into a first-class penal settlement. Although citizens and free settlers did not like him at all, because now they

had to take a back seat, the population increased rapidly.

	Total
1821	7,400 bond and free
1825	15,000
1835	25,000
1836	43,000—17,000 bond and 26,000 free.

The issue of free grants was completed by 1830, from then on land had to be purchased from the Crown, even though the best farmland had all been taken up.

Accounts of the pains of starting up farms are found in diaries. Building a house, digging land, and getting stock had all to be done at the same time. J. C. Sutherland wrote in his diary of 1823 how he sowed potatoes, onions, turnips, carrots, spinach and other vegetables, "planted two ridges of potatoes, fetched seven bushels of wheat, one bushel of barley, one hundred weight of potatoes and sowed them all". "He made a capital bedstead of wattles for his wife Lucy, and himself, the trees were cut in the morning". He also bought 100 ewes at 16/- (£80) and finished the hen house. He then set out to get salt from the salt pans. This salt was shovelled up during the summer months on the beds from several lakes. For that reason salt was always plentifully available in the diet of the free and the bonded V.D.L.ers. He "shore six of the longest woollen sheep and they were pretty well done for a first attempt". He found that it was not worth digging his potatoes "it proves so toilsome and improductive, the rest may remain in the ground". For Christmas dinner in 1824, they had "a big dinner of roast mutton and some whisky". Next year's Christmas fare was a bit better. "Anne, Lucy, Clara, dearest baby, and myself, had lots of pudding and a bottle of wine. Colin enjoyed himself over a potent tumbler of punch. The men received an extra joint of meat to roast, a pudding and a bottle of rum".

Another free settler's wife, Mrs. Fenton who accompanied her husband and her little daughter Flora, to open up land past New Norfolk in 1830, found that her little girl had lost all her colour and appetite. She feared that the nurse, "who is both ignorant and wilful, gives her when out of my sight such food as I do not permit". On her trip she asked at a private house for "a little milk, or a little sago or a little bit of anything for food for the baby". However, she was civilly informed that milk was never used and that children lived on fried meat and black tea. When finally settled, she had no bread, but "cakes of unleavened bread were baked in the hearth".

Life in Hobart Town appeared much softer. Henry Savery, describing a wedding breakfast celebrated on August 7, 1829, related that they had "not merely tea, toast and muffins, but a cold collation including the choicest productions of the farmyard as well as spoils of the sportsman. Things of all descriptions, rusks, buttered and covered with anchovies, shell fish, pies of various sorts, and a long list of jellies, trifles, blancmanges, custards, dried fruit, the whole crowned by a magnificent cake upon which the love of Pyramus and Thisbe was emblematically recorded".

For new settlers coming to V.D.L., Hobart Town shops looked very good in the 1830's. Jane Ann Brownell wrote to her sister in 1834 that she was now using good green tea at 1/8 per lb., which she bought in a chest which contained 80 lb. Sugar sold at 3¾d. per lb. by the bag of 100 lb. and coffee at 1/- per lb. Flour varied according to the price of wheat, which rarely exceeded 7/- per bushel, but was more generally 5/-; poultry, eggs, butter and milk were somewhat dearer than in England, but wine and spirits nearly one-half lower. She bought good Cape Wine as low at 3/6 per gallon.

Her father, Thomas C. Brownell, M.D., wrote to his brother in March, 1835, that he had 2 and 3 acres of potatoes and hoped to realise about 20 tons, generally worth about £5 per ton. He also had poultry, one milking goat and two kids. "The season will bring us abundance of wheat, potatoes, barley, turnips, etc.". John Espie's land on the east of Bagdad stream was very fine. Potatoes weighing 4 lb. each grew here.

Captives in V.D.L.

However, life was not so rosy and full of promise of better days ahead for little Peter McCann. In his unpublished diary he wrote about his life in Tasmania before he came over to Port Fairey to work for John Griffiths as head man of a whaling crew in 1837. He lost his mother at a young age, and was sent to the boarding school kept by Mr. and Mrs. Howard. "My first recollection of my school life was that I had travelled a long distance and that having arrived, late in the afternoon, I was very hungry. Shortly after my arrival the bell rang for tea, for which I was quite ready. Every boy was given a number which was placed by his mug of black tea and a small cube of bread with butter, the size of each cube varying according to the age of the boy, quite irrespective of any differences in appetite. Being hungry, I had gulped down my small morsel before I knew I had properly commenced. I went to bed hungry and got up empty, hoping that breakfast would be better. My hopes, however, were not realised. Then came dinner, composed of rough boiled meat with potatoes boiled in their skins and as much boiled stinging nettles as one could eat. No condiment other than salt was provided. The nettles were considered by the teacher to be the best and most economical blood purifier. I cannot remember how long I remained in this purgatory, but it must have been at least twelve months, and I may state here, that had it not been for the kind hearted charity of an old lady, that lived nearby, named Mrs. Daily, who was in the habit of sending us big dampers, as large as a moderately sized grind stone, I think we should have literally starved to death".

Free settlers had a diet which ranged from starvation diet to bounty, whereas the convicts had a more regular and reliable meal pattern during this period. For instance, prisoners regarded it as a privilege to be housed at Port Arthur, founded on October 30, 1830, because rations provided there were good.

Of the 16,069 convicts on the island, 931 were at Port Arthur, the military guard consisting of

a total of 52. In the first years many of the buildings of this model prison were erected by the prisoners. In the years 1836-1837-1838 extra work brought money in. Ships, boats and barges were built to the value of £2,000; moreover, ships' spares, cartwheels and boots were manufactured, and timber sawn to the value of £30,000. Farm and garden produce, potatoes, turnips and cabbages, up to the value of £2000, were produced at the same time.

The number of deaths each year at Port Arthur was far less than is usually thought. From the official records we learn the following:—

"Year	Deaths	Proportion
1830	none	
1831	none	
1832	4 drowned in harbour	1 in 69
1833	7	1 in 68
1834	27	1 in 27
1835	34	1 in 27".

Scurvy, caused by lack of fruit and vegetables, was not only found in Port Arthur, but also at Macquarie Harbour. Official reports indicate that there were seven cases of scorbutus at Port Arthur in 1830, 203 cases in 1831, 46 cases in 1832, 321 cases in 1833, 412 cases in 1834, and 26 cases in 1835.

The four basic types of rations at Port Arthur were based on the following types of food: flour, fresh and salt meat, some green vegetables or potatoes, some sugar, salt and vinegar if vegetables were not issued.

Ration Scales

Ration Scale No. 2, issued to convicts who were placed in situations of trust, such as clerks, overseers and watchmen, was as follows:—

18 oz. flour.
1 lb. fresh or salt meat *or* 10 oz. salt pork.
1 lb. green vegetables *or* ½ lb. potatoes.
½ oz. tea.
1 2/7 oz. sugar.
1/49 quart vinegar, when vegetables were not issued.
½ oz. salt.
½ oz. soap.

This was made into three meals:—

Breakfast.
½ lb. bread.
1½ pts. gruel made with 2 oz. flour.
1 pint tea.

Dinner.
½ lb. bread.
12 oz. salt beef *or* 6 oz. salt pork.
1½ pts. soup—made with 2 oz. of salt beef or salt pork plus whole vegetable ration and 2 oz. flour.
When fresh meat was used, soup was made from the whole allowance.

Supper.
½ lb. bread.
1½ pts. gruel.
1 pint tea.

Ration Scale No. 3 was issued to convicts on probation and was the same as No. 2, with the exception of 2/7 oz. sugar less and no tea at all.

Ration Scale No. 4 was issued to convicts on punishment gangs and was the same as No. 2 scales except that tea and sugar were completely excluded.

Ration Scale No. 5, issued to convicts sentenced to solitary confinement by the Police Magistrate on the Settlement, consisted merely of 12 oz. flour made into 1 lb. bread, ½ oz. salt and ½ oz. soap.

At Macquarie Harbour the rations were as follows:—7 lb. meat, 10 lb. flour per week. Assigned servants received half as much again and £10 per annum. No rations for vegetables or potatoes were issued.

The female convicts who were housed in the Female House of Correction in Hobart Town were not as well off.

Their daily ration was as follows:—1 lb. bread, 1 oz. sugar, 8 oz. meat, 1 oz. roasted wheat, 1 lb. green vegetables *or* ½ lb. potatoes, ½ oz. salt. Plus small amounts of certain other flavourings and thickening materials.

Again soup was made from the meat and vegetables and barley or peas were used to thicken it. In 1830 a special committee had been formed to determine the quantities of vegetables and peas or barley necessary to make 25 pounds of meat into 100 pounds of soup. The roasted wheat was used for making coffee. The nervousness and irritability of the women on this diet was attributed not to the mild or severe deficiency diseases they must have suffered, but to their antagonistic attitude. Women undergoing solitary confinement in a dark cell were given bread and water only. As the Female House of Correction also served as a maternity hospital, special rations were designed for nursing mothers.

The daily ration was:—1½ lb. bread, 1 pint milk, some oatmeal, ¾ lb. meat, some tea and sugar, ¾ lb. vegetables.

Infants were normally fed milk, bread, and sugar. Sick infants were given sago and wine, sago having been introduced as a replacement for poor quality bread.

Once the convicts had served their sentence, they were set free. Some would look for work. In the Journals of the Land Commissioner for V.D.L. we read that finding work and earning a living was not all clear sailing. The Commissioner wrote: "His Excellency may not understand the routine and expense of fencing. An instance which occurred the other day will put the matter in a clear point of view. On bargaining with two splitters, the rate of wages was as follows:—To split and put up four railed and morticed fence, by the rod or sixteen feet and half—four shillings and sixpence.

To pay the employer for—

mutton	6 pence per lb.
flour	2¼ pence per lb.
tea	8 shilling per lb.
sugar	9 pence per lb.
tobacco	8 shilling per lb.

When the job is finished a balance is struck and an order or Bill Field does the rest. Or in other words, after having lived miserably in the forest, buying little or no mutton, which would be a let off against them, but preying as they do on the neighbouring flocks, they take on orders for their money, or the cash itself to a publician in Hobart or Launceston and never quit the Public House until the proceeds of their labour is quite expended. Wheat, the staff of life, is the standard for wages in other countries, here, rum is the alpha and omega, such has been the mode of life for years of these prisoners, that without an inducement, such as obtaining rum, they will not work". In other words, the cost of food was to be deducted from their wages, therefore to minimise food costs, mutton was stolen from neighbouring flocks by the workers. When the job was finished the balance of pay minus food costs was received and exchanged for rum in a hotel. This hand to mouth existence of free convicts became a sizeable problem when more and more left prison after finishing their sentence.

1840-1850

In 1840, life must have been quite pleasant and food plentiful. Louisa Anne Meredith wrote that on their trip from Hobart to Oyster Cove they had "Toast, mutton chops, eggs, fried ham, a mighty teapot, and a comely mountain of home-made bread with an English bottle ale". And when once settled, she had "chickens, duck, and turkey to rear, butter, cream, cheese, and other country comforts to make and calves to feed. Mushrooms to pick and convert into ketchup. To visit the fields to see the wheat and oats growing and to cast an eye on the turnips and potatoes". Weary bush fire fighters were supplied with food, tea and cool cider, made from apples, grown in her orchards and processed on the farm.

In a description of the life of the Woods family of Sorell Valley, it is obvious that Mrs. Woods was not short of stores for her household. She could order any brand of tea (Tonkay, Imperial, Orange Pekoe) in packages of various sizes or in chests or half-chests, as well as West Indian sugar, East Indian rice, or West Indian coffee, Liverpool salt, Dutch mustard, Sydney and English cheeses. All these foods were shipped in, but the family grew plenty of food themselves—"Knopwood apples, red peaches, apricots, Orleans and Magnum Bomun plums, Kentish cherries, raspberries, gooseberries, and strawberries". For vegetables they grew black and kidney potatoes, onions, parsnips and carrots as main crops, and in addition, cabbages, cauliflowers, and lettuces. They had mutton from the flock, home raised pigs and salted, smoked pork, and chickens for Christmas and Easter. They also had honey from hives, which had been successfully brought into Tasmania in 1831. They made butter in round pats with a design of rose, thistle, shamrock or swan. Sponges would be baked in flat dishes and cakes made from risen dough with currants and sugar, plain cakes and fruit cakes, cherry pies in season and jam turnovers and boiled Christmas pudding.

Young fruit trees from V.D.L. found their way to the other States as early as 1841. Joseph May from Mount Barker, South Australia, complained in a letter to T. May in England in 1841, that he had not been able to get any fruit trees—"not living in Adelaide and going there very seldom, we do not know always when young trees from V.D.L. are for sale".

A "Mercury" article in 1883 mentioned that a lady on her wedding day on October 25th, 1845, had partaken of new potatoes, green peas, ripe strawberries, cherries, gooseberries, and currants. These were grown in Lane's garden at the foot of the Sandhill in Launceston.

The Judd family coming from England to Tasmania in 1842 were delighted with the Hobart shops and the low prices of food. Thomas Judd quoted the following prices in November, 1842: "Common wine is but 6d. and 8d. per pint, Scotch ale is 8d. per pint, beef 4d. to 6d., mutton 3d. to 5d., bread 7d., sugar 3d. to 4d., tea 3/-, 4/-, coffee 1/4 per lb., salt butter 1/6, fresh butter 1/9, cheese 1/4 per lb., tobacco 3/3, pepper 1/-, loaf sugar from London 8d.". The average rate of wages per diem to mechanics in Hobart Town in the year 1846 was 5/6 for plasterers, bricklayers, carpenters, painters, masons, and joiners, quarrymen got 3/-.

When land became difficult to get in Van Diemen's Land, free settlers began to look for fresh land and sailed over to Victoria where John Batman made his famous purchase of the site of Melbourne in 1835, John Fawkner from Launceston having followed soon after and the Henty brothers having left Launceston the year previously. Most sheep and cattle for Victoria were shipped from Tasmania as well as other supplies. Sheep worth 10/- now brought £2 and horses and cattle also brought good prices. Exports of wheat and flour brought in £140,000 during 1846. Other exports included fruit, to the value of £4,500, to other States. Hay, oats and potatoes were sold for £18,000. The first apple export outside Australia was in 1849 to New Zealand.

The convict population was still living on a ration scale. Regulations for hiring male and female probation passholders, of September 1st, 1847, state:—

> "Masters will in every case be required to provide suitable lodging and bedding for their servants without making any deduction from their wages, on that account. They will also be required to supply their servants with sufficient quantities of wholesome provisions and soap according to the following scale of daily rations:—
>
> 1 lb. meat.
> 1½ lb. bread *or* 1 lb. bread and 2 lb. vegetables.
> 1 oz. roasted wheat *or* ¼ oz. tea.
> 1 oz. sugar.
> ½ oz. salt.
> ½ oz. soap".

The aborigines who had been removed to Flinders Island as from 1830 could now also be counted under the captive part of the population. In November, 1831, the number captured was 54. In 1832, 63 more were captured, and 5 died on Flinders Island; in 1833, 42 were taken, 40 died

and 4 escaped; in 1834, 20 were taken but 14 died; in 1835, 17 were taken and 14 died, thus leaving 123 on Flinders Island in 1836, whereas in 1815 the numbers had been estimated at 5,000. The V.D.L. Royal Kalendar, 1848, related that "They have now been removed from Flinders Island, where they have been domiciled since 1833, to a station about 30 miles from Hobart Town, on the banks of the Derwent, called Oyster Cove. The country round the station is thickly wooded and abounds in such game as the aborigines delight in, viz, opposums, wallaby, etc., and the river abounds in fish of every description. The number of the aborigines removed from Flinders Island in October, 1847, is 45.

Each aboriginal native is rationed on the following scale:—

14 lb. fresh meat per week
10 lb. flour
3⅛ oz. tea
14 oz. sugar
3½ oz. salt
3⅛ oz. tobacco
3¾ oz. soap,

besides vegetables of every description. Cows are supplied to them which afford milk and butter, and pipes are found for them to smoke with. Their fondness for the conveniences of civilized life, which the Government have taken every means of ensuring to them, seems to be a guarantee for their good conduct and steadiness at the new station".

Prosperous conditions could not go on for ever. The land boom at Port Philip that followed the founding of Melbourne, had burst, prices slumped, sheep were sold at a shilling each. Merchants and land owners went bankrupt. Mrs. Meredith recorded that "When the price of wheat fell sharply, the family was thrown in financial difficulties". Her husband had to take a salaried post as police magistrate at Port Sorell. There was also much unemployment. To make things worse, more and more convicts were sent to V.D.L. and the Colony had to pay the expenses. In 1847, Van Diemen's Land was made the main penal settlement in Australia. Thousands of convicts arrived yearly under what was called the Probation System. These convicts were placed in over forty "probation stations" in different places on the island. They were supposed to cultivate the land, raise their food and vegetables and build bridges and roads in their own district. The great number of convicts and bands of now free convicts were of great concern to the free settlers. They demanded the abolition of transportation and the English Government agreed that transportation should stop in 1850. The name Van Diemen's Land, a name which had so many unhappy associations, was officially changed to Tasmania. A Legislative Council was appointed to govern Tasmania in 1851.

1850-1870

The years from 1850 to 1870 were not rosy. Whaling was finished and there was a slump in trade because as Victoria soon produced enough for her needs, imports from Tasmania were no longer required. Poor farming methods brought about declining crops of cereals and a reduction of stock. Heavier timbered areas were now tackled with axe and saw, and small selections were the result. These small settlers could always grow some of their needs. They produced milk and butter, grew vegetables, ground flour in small steel handmills and could always eat wallabies if there was no fat stock to slaughter. In this manner the North West Coast was opened up and after 1856 settlers came to Scottsdale and Ringarooma, then in 1875 orcharding started in the Huon, Tamar and Mersey valleys. Raspberries and currants were grown for the Hobart Town jam factories. A very good description of this toil on a small holding is found in the diaries of Robert and James Sawers (1861-1935), who came to Tasmania as little boys in 1854 from Scotland, to help their Uncle and Aunt on the farm on Hope Island, near Dover. Their labours were incessant and varied: clearing, stoning, and digging pieces of land, ploughing, and sowing enormous numbers of cabbages and potatoes, onions, carrots and mangolds, picking gooseberries, killing pigs, &c. This diary tells how in January, 1863, they were reaping barley and mowing oats. "Cut 20 cabbages by moonlight. Took another 20 dozen cabbages". Mowing wheat, Aunt made gooseberry and raspberry jam". "Uncle, John and James, carted in the barley before breakfast". "Churned the butter and took 11 lb. over to the Beach". "Filled 21 bags of barley. Sold 2 pigs to Bob and George for £2.0.0 a piece". "Received from the ship a piece of beef, ½ sheep and twine. Got 3/- and 3/6 for the cabbages".

The entries for February, 1863, run as follows:— "Cleaning barley in the sieve and weighted 86 bushels. Cut 47 dozen cabbages for town and carted 23 bags of barley to the vessel. Uncle baking. Uncle, Aunt, and I went over to the station. Aunt purchased at the new shop cheese— mustard, spice, coffee, sardines and lollipops. Pulling turnips in the big paddock. Uncle sowing cabbage seeds. Aunt finished the sewing of the main sail. Sent up 43 dozen cabbages. Purchased at the store shingle nails, lard and lollipops. Reaping wheat and turning up oats. Went over to the store for ¼ mutton, 3 lb. rice, and 2/6 of apples. Boat landed one cask beef, 3 bags flour, one sugar, a cask of apples, and ½ chest of tea". The 264 dozen cabbages sold in 1862 brought £36 9s. 6d., the hay £70 11s. 5d., the mangolds £3 12s. 6d., and for the butter £26 16s. 1d. were netted. The butter was sold for 1/- to 1/6 per pound. In 1882, their income had greatly increased, grains brought £150 7s., potatoes £20, pigs £80, hay £100, butter £80, Total of £430 7s. Sowing dates were carefully kept. In 1863 they sowed oats, barley, potatoes, peas, onions, carrots, parsnips, cabbages, mangolds, marrows, and radishes.

The cost of living in the 50's and 60's was fairly low. From an account book of a Launceston family we glean that a bottle of brandy was 6/-, rum 4/-, a gallon of rum 15/-, 5 gallons Old Tom £3 3s., a bottle of sherry 4/-, porter 3/-, a gallon beer 4/-, 1 dozen whisky £2 5s. This same account book mentioned purchases of a cedar table for 19/-, a double bedstead for £2, and a dozen knives for 11/-. The recipes in the same book look like those in any modern cook book, but recipes for

gout pills, aperient and stomach mixtures, bread poultices, and recipes for dysentry are scarce nowadays.

"The English and Australian Cookery Book. Cookery for the many as well as for the Upper Ten Thousand", by Edward Abbott of Tasmania, 1864, acquaints us thoroughly with many Tasmanian dishes and fishes. Recipes for game include guidance on how to cook kangaroo, and how to roast it, how to prepare kangaroo pasties, kangaroo steamer, also mentioned by Mrs. Meredith as "a delicious dainty dish", is a type of preserved kangaroo said to keep for 12 months or more. There are recipes for jugged kangaroo, and kangaroo hashed and pan jam, made from kangaroo tails. Sticker-up kangaroo is cooked on a stick, and for this the kangaroo is nicely divided into cutlets and spitted on a stick rammed into the ground close to the fire. A piece of bacon is fastened on the stick and drops fat on to the leaner steaks as they cook. Finally, the prize recipe in the kangaroo range:—

"Slippery Bob.

Method:—Take kangaroo brains and mix with flour and water. Make into a batter with pepper and salt, then pour a tablespoon at a time into an iron pot containing emu fat and take them out when done".

Other interesting dishes were roast emu—"resembles coarse beef in flavour, cannot be recommended unless one has a sailor's digestion". Mutton birds—"the eggs are good and largely used, and the feathers are made into beds of rather a fishy odour". Black swans—"when young they are tender and if properly roasted with good sauce, they are eatable and that is all we can say". Recipes for roast wombat and porcupine, wild pigeons, wattle birds and turkey bustards are also included.

Mundane recipes are given for colonial damper and colonial jam, made from mangolds and carrots. A special drink "Tasmanette" is made from a recipe received from Mr. Allport, who obtained a medal for it at the 1863 International Exhibition in England.

"**Tasmanette.**—In making jam—mulberry, Aldridge plums, morella and quince, after the sugar has been added, skim off and strain the surplus syrup. Keep in a dry place till all are ready, then add a tablespoon of vinegar to every pint".

An intriguing and more potent recipe is given for the beverage "Blow My Skull".

This dates from the days of Colonel Davey, who was called "Mad Tom Davey" by the settlers on account of his behaviour and parties often held with his officers and settler friends. It is said that at that time an invitation to dinner at Government House was accompanied by the polite request to bring your own bread. However, the drinks were free, and Colonel Davey challenged his guests to drink his Davey special: "Blow My Skull".

It was made in the following proportions:—

2 pints boiling water with enough loaf sugar, lime or lemon juice.
1 pint ale or porter.
1 pint rum.
1 pint brandy.

A very good and long list of the available Tasmanian fish is included in the same book—trumpeter weighing 1 lb to 40 lb., bass trumpeter, ling, horse mackerel, perch, magpie fish, trevalley or snotgall, mullet, king fish, snapper, 10 lb. to 12lb. barracouta, parrot fish, bream, whiting, conger eels, 20 lb. to an immense weight, flathead, rock cod, skate, hapuka—"Never heard anyone speak in its favour", flounder, carp, gar or guard fish, crayfish, 1 lb. to 7 lb., crown crabs, 1 lb. to 8 lb., oysters all sizes, scallops, mussels, cockles, whelks, perriwinkles, shrimps from Launceston, and very small lobsters.

The author was not impressed with the salmon of ½ lb. to 16 lb. "At times not fit for human consumption and numerous slight cases of fish poisoning have occurred from eating it. The fishermen say it is when the moon is at the full '(woe to the poachers)" but we rather think that, if not cooked soon after it is caught, it begins to putrefy. It is plentiful and cheap". As freshwater fish he listed eels, ½ lb. to 5 lb., "very abundant, and fine", sand fish, mullet "this fish smells like a cut cucumber", sand trout, 2-8 inches long, and lobsters.

1870-1900

When mining activities declined in Victoria, many diggers returned to Tasmania. They became prospectors and looked for gold only, but other metals were also found. Silver-lead was discovered at Penguin before tin was found at Mount Bischoff in 1871. In the N.E. the alluvial gold finds led to hard rock mining of gold at Lefroy and in the Mathinna-Mangana area. Beaconsfield on the West Tamar became a goldfield in 1877 when gold was discovered at Brandy Creek.

The success of the Mount Bischoff mine led to the opening up of the West Coast, i.e., first Mount Heemskirk in 1877, then Zeehan and later still Queenstown, Renison Bell and Rosebery.

Miners were often short of provisions. Supplies for Queenstown, e.g., were taken from Strahan by small rowing boats as far as possible up the river and from there were carried on men's backs to the miners.

In 1880, 52,595 oz. of alluvial gold were found to the value of £201,297, and 34,345 oz. gold were obtained from quartz, the value of which was £130,622. The five big gold companies returned £65,852 as dividends to their stockholders. In the same year tin exports brought £341,736. But although the Secretary of Mines wrote magnificent and jubilant annual reports, the quantities of mineral output declined rapidly and dividends dropped sharply. In 1881, the gold companies had paid out £99,250 in dividends, in 1890 it had fallen to £13,609. This should have warned investors that all was not well.

In Victoria another land boom had burst and caused a depression in Tasmania. This, together with the fact that much money had been wasted by incompetent management, by the purchase and erection of inadequate machinery, and by squandering of money for purely speculative purposes, caused the prevailing idea that the mining industry was decaying.

The first bank in Tasmania, called the Van Diemen's Land Bank, opened for business in 1824,

and paid 36 per cent dividend in 1826. It had to close its doors on August 3, 1891. This bank failure created great consternation and distress to the colony and was, as an official statement mentioned, due to "overtrading in securities of insufficient values".

Account books of private individuals indicate that some people were not hit. Mr. R. Hickman of Lenah Valley still bought crays and salmon at 6d. and the costs of his wife's and children's clothes, shoes and hats showed no sign of curtailed expenses. He still bought large quantities of fruit for his jam factory and paid for raspberries 2½d. per lb., blackcurrants 2d. per lb., red currants 1½d. per lb., Kentish cherries ¾d. per lb.

The Sawers boys from Scotland, grown up by now, closed off their dealing with the Van Diemen's Land Bank on July 27th, 1891, and received their new cheque book from the Commercial Bank early in August. However, many families now living in Tasmania can tell the sad tale of the reduced circumstances which befell their forebears due to the bank failure in 1891.

From the above account it can be seen that not very much information about the food habits and actual food intakes is available from the period of 1800-1900.

This may have been caused because some historians feel that this sort of information actually "mars" historical accounts. Even the second half of last century leaves us guessing as to what the daily diet consisted of.

However, abundant documentation by anthropologists, sociologists, economic historians and also by commercial enterprises who spent colossal sums on consumer preference surveys, should make the study of changing food patterns much easier in this, the 20th century.

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TWIN FOETUSES IN THE SOUTHERN ELEPHANT SEAL, MIROUNGA LEONINA (L.)

By

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[Communicated by Dr. W. Bryden.]

The Southern Elephant Seal, *Mirounga leonina* (L.) generally gives birth to a single pup, but occasional twins have been suspected based on the presence of two pups suckling from one cow (Angot, 1954; Laws, 1956; Carrick, Csordas and Ingham, 1962). Only one almost definite case of twins has been described in this animal (Carrick *et al., loc. cit.*). One case of conjoined twins has been described (Laws, 1953), and another mentioned (Laws, 1956).

The observation of actual births or the presence of two foetuses within the uterus is the only real proof of twinning in the elephant seal. Foster mothering of pups separated from their mothers is possibly not uncommon, since pups and their mothers can often be separated in the harems. On 15th September, 1965, I observed a pup which had been separated from his mother approach a pregnant cow, yapping continuously. The cow first objected to the approach, then rolled on her side and allowed the pup to nuzzle her abdomen searching for a nipple. The pup found the nipple and vainly sucked at it intermittently for three minutes before giving up and going to sleep. This cow was later separated from the pup by the movement of the bull in the harem and later the pup was rejoined by his mother.

Carrick *et al.* (*loc. cit.*) refer to the common occurrence of foster mothering later in the lactation period of cows.

On 10th September, 1965, a cow was dissected and found to be carrying twin foetuses, although one had apparently been dead *in utero* for a short time. Both foetuses were females, and each was attached to a separate placenta. The right ovary contained a single corpus luteum. The two foetuses were contained in the right cornu of the uterus, the left cornu being entirely empty. Data obtained from the cow and foetuses were as follows:—

	Length*	Weight
Cow	261.0 cm	—
Foetus 1	122.0 cm	44 Kg
Foetus 2	98.5 cm	23 Kg

The eyelids were not fused in either foetus. In the case of foetus 2 the eyes were sunken and the skin was relatively non-elastic. When the uterus was first opened the umbilical cord of this foetus was seen to be twisted around its body just in front of the pelvis. The placenta of this foetus was somewhat discoloured, but there were no signs of necrosis or infection in the uterus. It is considered that the twisted umbilical cord was most likely the cause of death of the foetus and had this not occurred there is no apparent reason why the two foetuses could not have been born alive.

* The length was measured in a direct line from nose to tail in each case.

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Note.—This paper was written whilst the author was working at Macquarie Island, 1964-66.

Diagrammatic representation of position of twin foetuses.

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MARCASITE AT RENISON BELL: ITS OCCURRENCE

By

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ABSTRACT

Despite a possible earlier abundance, marcasite at Renison Bell is today, an elusive, supergene mineral found only between undisturbed gossan and oxidising pyrrhotite. It is a transitional product in the formation of limonite boxwork.

BACKGROUND

For more than fifty years marcasite has been reported at Renison Bell where massive pyrrhotite is being mined for its cassiterite content. Ward (1909) reported it as being "always present" on the surface of exposed pyrrhotite, Reid (1925) as forming "large bodies" at the intersections of faults and ore sills, and Conder (1918) as being recent, i.e., post-mine, formed where pyrrhotite oxidises with a limited supply of oxygen. These three authors believed the marcasite to be supergene.

Stillwell and Edwards (1943), on the other hand, believed the marcasite to be hypogene, formed by "solution of the pyrrhotite in carbonate solutions which developed during the late stages of crystallisation of the lodes. The dissolved iron sulphide was reprecipitated, as fine pyrite, sometimes as fine marcasite, when it commonly shows a finely banded, colloform structure." These authors describe the marcasite as being in parts of the orebodies, particularly at the Black Face . . . the dominant sulphide.

The present study was undertaken to determine whether marcasite was indeed present, whether it was as common as the above descriptions seemed to indicate, and whether it was hypogene or supergene. All workings known up to 1961 were searched, over 3000 feet of drill core inspected, and 75 carefully polished sections (from DDH's 48 and 60) examined. Selected specimens were subjected to the classic $AgNO_3$ stain test (Dana-Ford 1932) and were X-rayed.

RESULTS

No marcasite could be identified with certainty in the field, or in the hand specimen, or in drill cores whether polished or unpolished. At the surface pyrrhotite where dry and well-drained, exfoliates to form tough rounded boulders covered with scales of iron oxide; where damp and sheltered from the sun, it crumbles to a black powder.

Specimens in which marcasite might conceivably—on the basis of colour or tarnish—have been present were boiled in a 3 per cent solution of $AgNO_3$ for 50 minutes. It soon became evident, as no doubt others have found, that determinations made solely on the basis of $AgNO_3$ staining were misleading for samples tentatively identified as marcasite proved on X-ray analysis, to be pyrite (Table 1).

The only locality where marcasite was discovered was in a zone a few feet thick between undisturbed gossan and pyrrhotite at Dunn's Workings. Specimens are medium grey in colour and are covered with yellow and greenish-white encrustations of sulphur and ferrous sulphate. The specimens when cleaned, showed under the stereomicroscope a reticulated oxidation boxwork—a more advanced stage of Gilbert's (1924) "gratings". The walls of the boxwork are composed of layers of a grey and a fine sugary, brassy material.

After impregnation and polishing the brassy material is seen, under oil immersion, to consist predominantly of colloform, botryoidal pyrite with minute angular patches and finely decussate specks of lighter coloured, pleochroic marcasite. The pyrite is of at least two generations or sub-generations one of which is intimately associated with the marcasite. Both pyrite and marcasite appear to be supergene. Identification of the marcasite was confirmed by X-ray.

CONCLUSIONS

Marcasite at Renison Bell is elusive and supergene. Because no gossans are today being stripped, it is not now "always present" at the surface. It appears only between undisturbed gossan and oxidising pyrrhotite and is a transitional product in the formation of limonite boxwork. Marcasite at other localities (Foslie 1950; Marmo 1953) may similarly be transitional.

ACKNOWLEDGEMENTS

William Petruk of the Mines Branch, Ottawa, confirmed and identified the marcasite from Dunn's Workings. Ramsay Ford and George Chao undertook miscellaneous X-ray analyses. The work was begun at the University of Tasmania.

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TABLE 1

$AgNO_3$ STAIN AND CONFIRMATORY TEST (WITH STANDARDS)

Sample	Locality	Description	Reaction: Tarnish	Tentative Identification	X-ray
B 2	Battery Fault	Vertical vein 2" wide	Brown and blue patches: minute black crystals produced	Pyrite and marcasite	Pyrite
B 3a	" "	Vertical vein 1" wide	Brown and blue patches	Pyrite, some marcasite	n.d.
B 3b	" "	" " " "	" " " "	" " "	n.d.
B 4	" "	Vertical vein 10" wide	" " " "	" " "	n.d.
B 8	" "	"Stepped" crystals along main fault	Negative: no reaction	Probably pyrite	n.d.
28	Montana South Lower Workings	Sample on mine dump	Brown and blue patches	Pyrite and marcasite	Pyrite
82	Dunns Workings	Sample from decomposing pyrrhotite	" " " "	Pyrite, some marcasite?	n.d.
125	Cable Workings	Loose float	Brown tarnish only	Pyrite	n.d.
198	Montana North N-S Cut	With quartz from wall of cut	Blue tarnish only	Marcasite	Pyrite
201	Battery Cut	Vein east wall of cut	Negative: sample crumbles	?	n.d.
209	Black Face	With quartz, capping pyrrhotite	Blue tarnish only	Marcasite	Pyrite
252	Central Cut	"Stepped" crystals with quartz	Nondescript motling	Pyrite?	n.d.
383	DDH S53	With quartz at 157 ft.	Brown, some bluish veinlets*	Pyrite, some marcasite	n.d.
451	DDH S60	Base of pyrrhotite at 167 ft.	Brown and blue	Pyrite, some marcasite	Pyrite
457	DDH S71	With carbonates at 238 ft.	Silver pp. on gangue, pyrrhotite blue-black, pyrite unaffected	Pyrrhotite + pyrite	n.d.
—	Main Road	Spherulitic concretion 1½" long along lamination (bedding) of "slates"	Negative: specimen crumbles	Marcasite?	Pyrite
Standard 1	Egremont, Cumberland, U.K.	Marcasite, Krantz collection	Negative: no tarnish	?	Marcasite
Standard 2	Welkeunaedt (Belgium ?)	" " "	" " "	?	n.d.

**Microscopic examination (anistropy, colour) suggests that the veinlets are marcasite*

OBSERVATIONS ON SOME TASMANIAN FISHES: PART XIV

By

E. O. G. Scott

(With one text figure)

ABSTRACT

Four species are added to the Tasmanian list: *Neoodax frenatus* (Günther), 1862 [Neoodacidae], *Petraïtes phillipi* (Lucas), 1891 [Clinidae], *Cristiceps argyropleura* Kner, 1865 [Clinidae], *Ophiclinops varius* (McCulloch & Waite), 1918 [Ophiclinidae]; some general observations are made on each of these. Other species are discussed as follows. Syngnathidae: *Stigmatopora nigra* Kaup, 1856 (supernumerary opercular keels), *Syngnathus curtirostris* Castelnau, 1872 (dimensions and proportions, meristic features including data on termination and origin of body ridges, regional intensity of ground color). Neoodacidae: comparative observations on all Tasmanian species except *Neoodax attenuatus* (Ogilby), 1897. Clinidae: *Clinus perspicillatus* Cuvier & Valenciennes, 1836 (dorsal and anal radial patterns, tentacles), *Clinus puellarum* Scott, 1955 (general account of a third Tasmanian specimen), *Petraïtes heptaeolus* (Ogilby), 1885 (further records), *Petraïtes johnstoni* (Saville-Kent), 1886 (tentacles), *Petraïtes forsteri* (Castelnau), 1872 (tentacles), *Cristiceps australis* Cuvier & Valenciennes, 1836 (tentacles). Rostral and ocular tentacles of the Tasmanian clinids are figured.

INTRODUCTION

This paper follows the general plan of others in the series. The symbols *Ls, Lt* denote standard length, total length, respectively; *TLs, TLt* signify thousandths of standard, of total, length. Except where otherwise indicated, all linear dimensions are in millimetres, the name of the unit normally being omitted. 'Ordinary' or unadjusted standard deviation, using n (not n-1), has been calculated, regardless of size of sample. Where two, or more, specimens are noted in one context, the sequence of citation of the relevant specification is that of increasing size of individual fish, as measured by *Ls* (rarely, if *Ls* is not conveniently determinable, by *Lt*). Locality records include county names.

Family Syngnathidae

Genus **STIGMATOPORA** Kaup, 1853

STIGMATOPORA NIGRA Kaup, 1853

Stigmatopora niger Kaup, 1853, *Arch. Naturges.*, XIX, 1.233:*nomen nudum*. Type locality: Tasmania.

Stigmatophora nigra Kaup, 1856, Cat. Lophobr. Fish. Brit. Mus.: 53. Type locality: Tasmania (Verreaux).

Supernumerary opercular keels.—Characteristically a well marked and complete opercular keel is present at all stages of growth—a point of distinction from *S. argus* (Richardson), 1840, in which a keel is usually developed feebly in young, but is almost invariably absent in adults. In a specimen, *Lt* 166.0, caught in Scamander River, Cornwall, in green weed near the bank, by Mr K. Lidgerwood on 15th November 1964 an abnormal set-up occurs. A single normal keel traverses the right operculum in an almost straight line (anteriorly briefly concave upward; net direction backwards and slightly upwards), originating quite close to its anterior margin, at level of lower one-third of eye, and ending slightly above the middle of its posterior border. On the left operculum are two additional keels, both lying beneath the normal one. The first arises from the primary keel, at about its anterior one-sixth, and runs back almost in a horizontal line (slightly concave anteriorly, slightly convex posteriorly) to the hind opercular margin. The second originates independently, a trifle nearer to the level of the front of the primary keel than to the point of confluence of the first supernumerary keel, and continues backwards and downwards, in a gently convex curve, for rather less than half the distance between its origin and the free opercular border.

Two distinct keels joining immediately behind the eye are described in the South Australian *Corythoichthys flindersi* Scott, 1957 [later (1962: 117) transferred by its author to *Syngnathus* Linné, 1758; in Whitley's name-list of the fishes recorded from Australia (1964: 38) it is entry 488, *Parasyngnathus* (*Vanacampus*) *flindersi* (T. D. Scott, 1957)]. The illustration (fig. 2: 182) would seem to raise a question as to whether the upper ridge there depicted is an opercular keel in the usual connotation of the term, or whether it possibly represents the upper border of the operculum; but the point cannot be determined without examination of specimens. In *Stigmatopora nigra*, as in some other species, the superior border of the operculum is normally delimited by a low narrow upcurving line or incipient ridge.

Genus **SYNGNATHUS** Linné, 1758

SYNGNATHUS CURTIROSTRIS Castelnau, 1872

Syngnathus curtirostris Castelnau, 1872, *Proc. Zool. Acclim. Soc. Vict.*, 1:243. Type locality: St Vincent's Gulf, South Australia.

Material.—Specimens (*a*)-(*i*); *Ls* 85.7, 91.7, 102.2, 102.7, 102.8, 106.9, 113.8, 120.3, 140.1; *Lt* 87.2, 94.0, 104.4, 105.0, 105.0, 108.9, 116.1, 123.1, 143.1; part of a large collection of various rock-pool fishes taken with rotenone by Mr R. H. Green at Green's Beach, Devon on 4th and 5th August 1965.

Earlier sample.—Data here presented largely supplement and complement data given earlier in these observations (1964) for a sample of 7 specimens, *Ls* 56.2-97.9, $\bar{x}$ 85.67 ± 5.17, from Clarence Point, Devon.

Dimensions, proportions.—Dimensions in mm and proportions as *TLs* of the present sample are set out in Table I. Where significant regression of *TLs* (*Y*) on *Ls* (*X*) obtains, the regression equation, along with its *t*-value, and the estimated values (*Y*) of *Y* for individual fish also are recorded. For those regions the *TLs* value of which as set out in the table comprises only 2 digits a *TLs* of 3 significant figures has been used used in the calculation of the regression equation, so ensuring that full use is made of the available degree of precision of the actual measurements. (It should be noted that whereas in the earlier data (1964, Table I, Table II) proportions are calculated relative to *Lt*, the standard of overall length here adopted is *Ls*.) Inspection of the table shows that the four magnitudes exhibiting significant regresison on *Ls*—snout, eye, interorbital, head—all exhibit a decrease in size relative to overall size of fish. For the remaining entries—which, except in so far as dorsal termination extends shortly beyond the vent, are precaudal—the coefficient of *X* in the (non-significant) regression equations is also negative. Though the neat unbroken run with which *TLs* values for precaudal length decrease to the right in the table (with increasing *Ls*) encountered in an earlier sample of this species (1964, Table I) is not duplicated in the present series, the available evidence is consonant with the situation found in the previous investigation—namely, relative decrease in length to vent, with concomitant relative increase in length of tail, associated with increase in general size of fish. With the earlier sample an attempt was made to investigate the possible existence of a regular growth rate gradient in the various anteroposterior segments of the precaudal length. This was done by calculating for each of the segments the percentage increase in length of specimens (*b*)-(*g*) on specimen (*a*) (smallest), and comparing the results with data similarly arrived at in the case of total length (1964, Table II). Arithmetic means thus obtained, with *Lt* as unity, are as follows (values for present sample, with *Ls* as unity, in parentheses): snout 0.68 (0.98), eye 0.53 (0.73), postorbital head 1.24 (0.87), head 0.88 (0.48), trunk 0.90 (0.98), preanal region 0.89 (0.94), tail 1.06 (1.48). No satisfactory evidence for a simple pattern of growth gradient emerges. For dorsal base, which is partly precaudal, partly caudal, the earlier value was 1.11; for the present material it is 1.10.

Conspectus specifications.—A conspectus of Tasmanian syngnathids (Scott, 1961) provides, as the first 8 entries for each species, the minimum and maximum values, as recorded in the literature, for a count or body proportion. Values of these 8 items for the present material (with conspectus extremes—with some extensions derived from the Clarence Point sample (1964:85)—in parentheses) follow. Total rings 18, all specimens (18-19) + 41-47, $\bar{x}$ 43.7 ± 0.54 (42-47): subdorsal rings 0.1-1.0 + 3.9-5.2 [means 0.40 ± 0.13, 4.63 ± 0.20] (0-1 + 4-5): brood rings caudal 1-14, one specimen only (total 16): dorsal rays 20-24, $\bar{x}$ 21.8 ± 1.2 (20-24): eye in snout 1.8-2.1, $\bar{x}$ 1.99 ± 0.034 (1.8-3.0): snout in head 2.5-2.9, $\bar{x}$ 2.55 ± 0.012 (2.5-2.7): head in trunk 2.3-2.8, 2.49 ± 0.52 (2.4-3.5): trunk in tail 2.2-2.6, $\bar{x}$ 2.45 ± 0.057 (2.2-2.8). Of the present values three thus extend the conspectus entries, two numerically downward (head in trunk 2.3, brood rings 14), one numerically upwards (snout in head 2.9); while more precise values are recorded for the subdorsal annuli.

The statement concerning the earlier sample 'All our values for head in trunk (2.4-2.6) and for trunk in tail (2.5-2.8) , , , stand outside the accepted ranges' (the first numerically in deficit, the second numerically in excess) does not hold good for the present material; though, as noted above, the lower entry for head in trunk is here transgressed.

Pooled values for the two sets of material give frequency distributions of number of caudal annuli, number of dorsal rays as follows. For the 7 counts 41-47 caudal annuli frequencies are 1, 1, 1, 7, 4, 1, 1, respectively. For the 5 counts 20-24 dorsal ray frequencies are 3, 4, 3, 4, 2, respectively. All Tasmanian examples so far examined have 18 trunk annuli.

Size of eye.—Of the sample collected in 1962 it was remarked 'The reason for the distinctly [relatively] smaller eye in our material remains obscure—especially in view of the facts, first, that our specimens are smaller than those previously reported upon (McCulloch & Waite (1918) 2 males 2 females 125-164), and, secondly, that the published ratios take account of a Tasmanian example (from Low Head: *Lt* 142.8)'. Conspectus values for eye in snout, based on available published data at the time, are 1.8-2.1: for the 7 Clarence Point fish [specimens in ascending order of *Ls*: see Table I (1964:87)] the ratios are 2.6, 2.7, 2.5, 2.8, 3.0, 2.8, 2.8. The current sample affords no explanation for the earlier numerically high values; presenting magnitudes (2.0, 2.1, 1.8, 2.1, 2.0, 2.0, 2.0, 2.1, 1.9) having the same extremes as the original conspectus specification.

Meristic data. Meristic data incidentally noticed above are exhibited systematically, along with data for some other characters, in Table II. Three points call for comment.

(*a*) *Right and left body ridges.*—Table II supplements information previously given regarding variation in location, on the two sides of the fish, of the free end of the upper trunk (TU), median trunk (TM), and upper caudal (CU) ridges. Differences between right and left sides expressed as decimal fractions of the anteroposterior extension of one anulus are (of the two figures in parentheses the first applies to the earlier, the second to the present, sample): TU 0.0 (1, 2), 0.1 (4, 1), 0.2 (1, 2), 0.5 (1, 0), 0.7 (1, 0), 0.8 (0, 2), 0.9 (0.1); TM 0.0 (4, 2), 0.1 (2, 0), 0.2 (1, 1), 0.3 (0, 2), 0.5 (0, 1), 0.6 (0, 1), 0.8 (0, 1), 1.1 (0, 1); CU 0.0 (2, 0), 0.2 (1, 1), 0.3 (3, 1), 0.4 (0, 2), 0.6 (0, 3), 0.9 (0, 1), 1.0 (1, 1). Pooling for each type

of ridge observations on both sides, and specifying the point of termination (or of origin; CU) as a decimal fraction of the length of the relevant annulus (measuring from front; 0.0, 1.0 signifying, respectively, anterior, posterior margin), we find TU ends at 0.8 of second caudal ring (0, 1) and at 0.2 (0, 1), 0.3 (0, 1), 0.5 (1, 0), 0.6 (1, 0), 0.7 (1, 6), 0.8 (4, 0), 0.9 (3, 5), 1.0 (4, 1), of third caudal and at 0.1 (0, 2) 0.7 (0, 1) of fourth caudal: TM ends at 0.1 (0, 2), 0.4 (0, 1), 0.7 (0, 1), 0.8 (1, 2), 0.9 (0, 4), 1.0 (8, 6) of last trunk annulus and at 0.1 (4, 1), 0.2 (1, 0), 0.5 (0, 1) of first caudal: CU originates at 0.0 of penultimate trunk annulus (0, 1) and at 0.1 (0, 1), 0.2 (0, 1), 0.4 (5, 0), 0.5 (5, 1), 0.6 (2, 1), 0.7 (2, 1), 0.8 (0, 2), 0.9 (2, 0), 1.00 (0, 2), of last trunk and at 0.1 (2, 3), 0.2 (0, 1), 0.3 (0, 1), 0.4 (1, 2), 0.7 (0, 1), of first caudal. TU is thus seen to extend, in the pooled samples, over 2 annuli (second, third caudal; previously only third), TM over 2 (last trunk, caudal), CU over 3 (penultimate and last trunk, first caudal; previously only latter two).

It is thus apparent the usual practice of citing in a specific diagnosis a unique annulus for the end or beginning (as applicable) of one of these body ridges is of limited validity. The degree of variability now becomes a matter of interest. The relevant data obtained on treating points of origin and termination as continuous variates, measurable in annulus units are given in Table III; where the first three rows specify number of annuli to origin or termination of ridge counted caudad from first trunk annulus (and representing for TU, TM length of ridge; for CU unridged anterior annuli), and the last row, with data available only for current sample, specifies number counted cephalad from last caudal annulus (length of CU). In evaluating the results it should be borne in mind that in both our samples the number of the trunk, but not of the tail, annuli is the same for all individuals: for the species 18-19 trunk rings are recorded. The exceptionally early origin of CU on the left side of (*b*)—see Table II—increases the range of insertion of that ridge from 1.6 to 2.7 annuli. For the pooled sample the distribution is for all ridges leptokurtic, the number of entries lying within the range $\bar{x} \pm \sigma$ being 28, 27, 31 (expected, for normal distribution, 22) for TU, TM, CU, respectively. For the current sample, with an 'expected' number of 12, the number found is 14 for each of the first three distributions, 13 for the last (CU measured from terminal ring).

(*b*) *Supernumerary ridge.*—In specimen (*f*) of the earlier sample, *Ls* 97.0, CU was subcontinuous with an anomalous lateral ridge extending forward along trunk, above TM, for about 11 (left), about $10\frac{1}{2}$ (right) annuli. The supernumerary ridge of the smallest member of the present series specified in Table II has its beginning on left side just overarching, on right overarched by, termination of TM: the right ridge suffers a short interruption posteriorly.

(*c*) *Brood annuli.*—The conspectus entry is 16, without ordinal specification or indication of possible variation in number. On the ventral surface of (*f*) of the present sample two low ridges that presumably delimit an incipient pouch arise just behind vent, at their closest approximation rather less than one-third of width of the annulus apart; diverge rapidly; and from third annulus run back parallel, separated by about half width of ventral surface, to end of 14th ring.

Regional relative intensity of ground color.—The formal discussion of relative intensity in different regions (the three surfaces each of head, trunk, tail) in a single female, *Ls* 139.7, from Low Head, Dorset contained in an earlier contribution (1964: 91) is here complemented by the presentation of observations on the 9 examples of the the current example. Assessments of relative intensity have been made directly by eye (least confidence can be placed in entries for head, in which region the reduction in area of ground color, by abundance of pattern color, makes an accurate estimation of its intensity at times somewhat problematical).

The data are set out in Table IV. Capital letters refer to a color: A black, B very dark brown, C dark brown, D dark reddish brown, E medium brown, F light brown, G dark fawn, H light fawn, I whitish. Lower case letters identify specimens; with numbers in parentheses recording standard length. Numerals not in parentheses are used thus: occurring alone or to left of a decimal point 1, 2, 3 denote the primary (anteroposterior regions), trunk, tail, head, respectively (the sequence following general visual importance, in preference to spatial succession); occurring to right of a decimal point 1, 2, 3 denote the secondary regions (surfaces), lateral, dorsal, ventral, respectively. The entries $>$, $<$, $=$ signify, respectively, deeper than, lighter than, equal in intensity to, ground color of secondary region adopted as standard of comparison. Conventional scores are found by counting $>$ as $+1$, $<$ as -1, $=$ as 0, and summing. Conventional net scores at right provide a conventional estimate of the extent to which a given relative intensity obtains within the sample. Totals of conventional scores, at bottom of table, give for each individual a conventional sum, for the pattern of specification used in the table, of relative intensity values, first, for the three primary or anteroposterior regions, secondly, for the three secondary or superficiary regions.

Considerable individual variation is apparent, only two entries having a conventional net score of 9, the ventral surfaces of the head and the tail being invariably darker than the ventral surface of the trunk. The lateral surface of the tail is at once predominantly darker than the lateral surface of the trunk and lighter than the dorsal caudal surface; again, dorsal caudal is overall darker than trunk or head dorsal: other relations can be determined from the table. In the present inquiry variation in intensity along the anteroposterior axis at an infraregional level (*i.e.*, sectionally within head, trunk, tail) has not been investigated: but the broad picture emerging from such a treatment of the specimen reported upon in 1964, namely, an anteroposterior gradient of ground color intensity with a point of inflection of least intensity at the back of the head would seem to find confirmation at regional level here.

TABLE I

Syngnathus curtirostris Castelnau, 1872. Sample of 9 specimens, *Ls* 85.7–140.1, $\bar{x}$ 107.36 ± 5.05 mm, from Green's Beach, Devon, Tasmania. Dimensions, as measured (mm), and as expressed as thousandths of standard length (*TLs*) of 10 regions: where significant regression of *TLs* (*Y*) on *Ls* (*X*) obtains, the regression equation, with an indication (*t*) of its significance, and the estimated values of *Y* for individual fish also are recorded

Region		Specimen *Ls* : mm									Regression of *TLs* (*Y*) on *Ls* (*X*)	
		(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	(*h*)	(*i*)	Equation	*t*
		85.7	91.7	102.2	102.7	102.8	106.9	113.8	120.3	140.1		
Snout—												
Length	: mm	3.45	3.85	4.05	4.2	4.15	4.05	4.5	4.75	5.05		
TLs	: actual	40	42	40	41	40	38	40	40	36	$Y = -0.09121\,X + 49.37$	4.08**
	: estimated	42	41	40	40	40	40	39	38	37		
Eye—												
Diameter	: mm	1.75	1.8	2.05	2.0	2.05	2.05	2.2	2.3	2.7		
TLs	: actual	20	20	20	19	20	19	19	19	19	$Y = -0.01878\,X + 21.60$	2.78*
	: estimated	20	20	20	20	20	20	20	19	19		
Interorbital—												
Width	: mm	0.95	1.0	1.25	1.2	1.2	1.05	1.15	1.2	1.2		
TLs	: actual	11	11	12	12	12	10	10	10	9	$Y = -0.04908\,X + 15.94$	2.48*
	: estimated	12	11	11	11	11	11	10	10	9		
Head—												
Length	: mm	9.9	10.05	10.5	11.1	11.05	10.95	11.4	11.8	13.25		
TLs	: actual	116	110	108	108	107	102	100	93	95	$Y = -0.4200\,X + 149.42$	5.82**
	: estimated	113	111	107	106	106	106	102	99	91		
Pectoral—												
Length	: mm	1.9	2.05	2.2	2.2	2.25	2.15	2.2	2.4	3.05	..	..
TLs	: actual	22	22	22	21	22	20	19	20	22		
To dorsal origin—												
Length	: mm	31.0	32.2	36.7	36.9	36.3	36.5	39.95	41.0	4[illegible]	..	..
TLs	: actual	362	351	359	359	353	341	351	341	352		
To dorsal termination—												
Length	: mm	37.0	38.9	43.4	44.6	43.25	44.5	47.95	49.3	58.9	..	..
TLs	: actual	432	424	425	434	421	416	422	410	420		
To vent—												
Length	: mm	32.2	33.3	39.5	37.6	37.95	39.5	41.0	42.1	50.25	..	..
TLs	: actual	376	363	387	366	369	354	360	350	359		
Trunk (calculated)—												
Length	: mm	22.3	23.25	29.0	26.5	26.9	28.55	29.6	30.3	37.00	..	..
TLs	: actual	260	254	279	258	262	252	260	257	267		
Dorsal base (calculated)—												
Length	: mm	6.0	6.7	6.4	7.7	6.95	8.0	8.0	8.3	9.65	..	..
TLs	: actual	70	73	76	73	68	75	70	69	69		

TABLE II

Syngnathus curtirostris Castelnau, 1872. Meristic characters of 9 specimens, *Ls* 85.7 – 140.1, $\bar{x}$ 107.36 ± 5.05 mm, from Green's Beach, Devon, Tasmania

Feature	Specimen								
	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	(*h*)	(*i*)
Dorsal rays	21	21	20	23	21	21	23	22	24
Trunk annuli	18	18	18	18	18	18	18	18	18
Tail annuli	42	44	43	41	44	45	47	44	44
Annulus (with decimal fraction), on which dorsal originates	17 (0.8)	17 (0.8)	17 (0.9)	18 (0.1)	18 (0.0)	17 (0.9)	17 (0.9)	17 (0.8)	18 (0.2)
Annulus (with decimal fraction) on which dorsal terminates	22 (0.9)	22 (0.9)	22 (1.0)	23 (0.2)	23 (0.1)	22 (1.0)	23 (0.2)	23 (0.2)	23 (0.2)
Annulus (with decimal fraction) on which TU terminates .. right	21 (0.7)	21 (0.7)	21 (0.9)	21 (0.9)	22 (0.1)	22 (0.1)	21 (0.2)	21 (0.7)	21 (0.9)
left	20 (0.8)	21 (0.7)	21 (1.0)	22 (0.7)	21 (0.9)	21 (0.3)	21 (0.9)	21 (0.7)	21 (0.7)
Annulus (with decimal fraction) on which CU originates .. right	19 (0.1)	18 (0.0)	18 (0.8)	19 (0.2)	19 (0.7)	19 (0.4)	18 (1.0)	19 (0.1)	19 (0.3)
left	19 (0.4)	17 (0.0)	18 (0.2)	18 (0.6)	19 (0.1)	18 (0.5)	18 (0.8)	18 (0.7)	18 (1.0)
Annulus (with decimal fraction) on which TM terminates .. right	18 (0.1)	18 (0.9)	19 (0.5)	18 (1.0)	18 (0.4)	18 (0.9)	18 (1.0)	18 (0.8)	18 (0.8)
left	18 (0.9)	18 (0.9)	18 (1.0)	18 (0.7)	18 (1.0)	18 (0.9)	19 (0.1)	18 (1.0)	18 (1.0)
Annuli (with decimal fractions) between which supernumerary mid-lateral ridge extends .. right	18 (0.1)–17 (0.1)+	..	..	..	..	..	..	..	..
left	19 (0.2)–19 (1.0) 18 (0.0)–36 (0.2)	..	..	..	..	..	..	..	..
Annuli (with decimal fractions) between which ridges of rudimentary brood pouch extend	..	..	..	..	..	..	19 (0.0)–32 (1.0)	..	..

TABLE III

Syngnathus curtirostris Castelnau, 1872. Specification of lengths of body ridges, upper trunk (TU), median trunk (TM) and upper caudal (CU), treated as continuous variates, measured in annulus units: for TU, TM annuli counted caudad from first trunk annulus, for CU caudad from first trunk annulus (upper entry) and cephalad from last caudal annulus (lower entry): observations made on both sides of fish. Earlier sample, 7 specimens, from Clarence Point, Devon, Tasmania specified previously (1964 : 85), present sample, 9 specimens, specified in this paper

Morphological feature measured (annuli)	Ridge	Present sample				Pooled sample			
		Range	$\bar{x}$	σ	V	Range	$\bar{x}$	σ	V
Ridge length ..	TU	20.8–22.7	21.77 ± 0.092	0.39 ± 0.065	1.8 ± 0.07	20.8–22.7	21.78 ± 0.070	0.40 ± 0.050	1.9 ± 0.2
Ridge length ..	TM	18.1–19.5	18.83 ± 0.078	0.33 ± 0.055	1.8 ± 0.06	18.1–19.5	18.92 ± 0.048	0.27 ± 0.035	1.4 ± 0.2
Pre-ridge length ..	CU	17.0–19.7	19.00 ± 0.14	0.61 ± 0.10	3.2 ± 0.1	17.0–19.7	18.75 ± 0.22	1.22 ± 0.15	6.5 ± 0.8
Ridge length ..	CU	40.8–47.2	44.01 ± 0.42	1.76 ± 0.29	4.0 ± 0.7	..	..	..	..

TABLE IV

Syngnathus curtirostris Castelnau, 1872. Regional relative intensity of ground color in 9 specimens, *Ls* 85.7–140.1, $\bar{x}$ 107.36±5.05 mm, from Green's Beach, Devon, Tasmania

For explanation see text

Primary region (antero-posterior segment)	Secondary region (surface)	Secondary region as standard of comparison	Specimen (*Ls*, mm) (*a*) 85.7	(*b*) 91.7	(*c*) 102.2	(*d*) 102.7	(*e*) 102.8	(*f*) 106.9	(*g*) 113.8	(*h*) 120.3	(*i*) 140.1	Conventional net score x=*i* Σ x x=*a*
1	1.1	..	B	D	C	A	E	C	C	C	F	..
	1.2	1.1	<	=	>	=	>	=	=	>	>	3
	1.3	..	B	G	H	D	H	H	G	I	I	..
2	2.1	1.1	>	>	=	>	>	>	=	<	>	5
		2.2	<	>	<	>	<	<	<	<	<	−5
		2.3	<	<	>	>	>	>	<	>	<	1
	2.2	1.2	>	>	>	>	>	>	>	>	<	7
		2.1	<	<	>	<	>	>	>	>	>	3
		2.3	>	<	>	>	>	>	>	>	<	5
	2.3	1.3	>	>	>	>	>	>	>	>	>	9
		2.1	>	>	<	<	<	<	>	<	>	−1
		2.2	>	>	<	<	<	<	<	<	>	−3
3	3.1	1.1	=	=	<	=	>	>	>	>	<	2
		3.2	>	>	=	=	>	>	<	>	=	4
		3.3	<	<	<	=	>	>	=	>	=	0
	3.2	1.2	=	<	<	=	=	>	=	<	<	−3
		3.1	<	<	=	=	<	<	>	<	=	−4
		3.3	<	<	<	=	>	>	=	>	=	0
	3.3	1.3	>	>	>	>	>	>	>	>	>	9
		3.1	>	>	>	=	<	<	<	<	=	−1
		3.2	>	>	>	=	<	<	<	<	=	−1
Totals: conventional score		N=3 Σ 1.N N=1	−1	−1	0	−1	0	−1	−1	0	0	−5
	N=3 Σ N.N N=1	N=3 Σ 2.N N=1	2	7	3	3	3	3	2	3	−2	24
		N=3 Σ 3.N N=1	1	0	−1	1	..	3	−2	1	−3	−2
		N=3 Σ N.1 N=1	1	1	−2	3	3	4	−2	4	−4	8
	N=3 Σ N.N N=1	N=3 Σ N.2 N=1	−4	0	0	1	0	4	2	3	−2	4
		N=3 Σ N.3 N=1	6	5	4	−1	−1	−3	−1	−3	1	5

Family NEOODACIDAE

The four species credited to Tasmania in the Check-List—*Olisthops cyanomelas* Richardson, 1850; *Haletta semifasciata* (Cuvier & Valenciennes), 1840; *Neoodax balteatus* (Cuvier & Valenciennes), 1839; and the endemic *N. attenuatus* (Ogilby), 1897—together with *N. radiatus* (Quoy & Gairnard) 1853, first recorded for Tasmania in Part XII of these Observations, have been keyed in that paper (1964:97).

Neoodax frenatus (Günther), 1862 is here added to our list. In the key mentioned it would follow reference number 4, being distinguished from the species in couplet 4 thus: from *N. balteatus* by a greater (31, against 28-30), from *N. attenuatus* by a smaller (31 against 35), number of dorsal radial elements (spines plus rays); and from both these species by a smaller number of anal radial elements (13, against 15, 19, respectively).

Some comparative proportions, as *TLs*, of local examples of all the Tasmanian species, with the exception of *N. attenuatus*, which does not seem to have been satisfactorily recognized since it was described, are exhibited in Table V.

Genus **NEOODAX** Castelnau, 1875

NEOODAX FRENATUS (Günther), 1862

Odax frenatus Günther, 1862, Cat. Fish. Brit. Mus., IV:241. Type localities: Fremantle and Gages Road, Swan River, Western Australia.

Tasmanian record.—An example, *Ls* 152.2, *Lt* 193.5, was obtained in the Tamar River, Dorset/Devon, on 23rd July 1965 by Mr E. W. Gatenby (Queen Victoria Museum Reg. No. 1965.5.6). The species has hitherto been known only from Western Australia and South Australia.

Meristic data.—D. xviii, 14 A. iii, 10. V. i, 4. P. 10 (left), 12 (right). C. 15 (all counted), 12 main rays. L. lat. 41. L. tr. 3/11.

Remarks.—Body ratios in general agree satisfactorily with those given in the original description, based on an example 56 lines in total length. Those noted by Günther (with values for the present specimens in parentheses) are: height of body eight (7.0), head four and a third (4.6), caudal, 6 (4.7) in total length. Pectoral a little shorter than (0.72 of) ventral, two-fifths (0.45) of head.

A fairly full series of proportions of the present example, expressed as *TLs*, are set out in Table V, side by side with corresponding data for three other local neoodacids.

Scales cover the whole of the space between the preopercular ridge and a very narrow naked rim round the orbit to a little in advance of hind border of eye, somewhat irregularly arranged in from 2 rows (above) to 4 or 5 rows (below). Beneath eye lies a smooth lanceolate facet extending horizontally from about one-third of an eye-diameter in advance of orbit to level of hind border of orbit, its borders, the lower of which is the subocular segment of the preorbital ridge, sharply defined and slightly elevated. The area between this facet and lower border of eye is filled by the continuation of the scales already mentioned, which thereby come to extend as far forward as front of pupil, in advance of which they are reduced to a short single series. Small scales occur also on the vertical limb of the preopercular between its posterior border and the preopercular ridge, reaching at least as far forward as the posterior one-fourth of the genal facet. Operculum covered with scales: those on the upper part are about the same size as, or a little larger than, those on the upper part of the preoperculum; those of the lower part—exhibiting, unlike their preopercular counterparts, little decrease in size—are up to twice as large as those on the preoperculum at the same horizontal level. Several scales on posterior half of suboperculum. Preopercular border entire.

Coloration.—General color rather dark green, somewhat darker and more brownish on dorsal surface, somewhat lighter, and, in parts, more yellowish, on lower half of flank, and on ventral surface; some silver anteriorly on throat. On left side a row of pink scales along lateral line. Head: above concolorous with darkest portions of dorsal surface of body; on side green in lower half, lightest on genal facet, a horizontal dark, almost black, bar through eye covering almost whole of snout above mouth and continuing back to end of operculum, several light golden lines on cheek: on ventral surface pale greenish yellow. Dorsal anteriorly concolorous with body, but having at several points basal blackish and bright magenta splashes; posteriorly lighter in general color, becoming, rather suddenly, very light straw, with some dark green basally and with some basal and scattered pale red. Anal chiefly lettuce green in anterior half; yellow or pale orange, with some greenish tinge, in posterior half. Caudal wholly green, save for a dull bronze flush at base and on proximal half of some of the middle rays. Pectoral orange, with dark green basal bar, and with some distal green. Pelvic spine green, first ray brownish, second dark green, inner two dirty white.

NEOODAX RADIATUS (Quoy & Gaimard, 1835

Malacanthus radiatus Quoy & Gaimard, 1835, Voy. *Astrolabe*, Zool., III: 717, pl. XIX, fig. 2. Type locality: King George's Sound, Western Australia.

Neoodax radiatus (Quoy & Gaimard). McCulloch, 1929, *Mem. Aust. Mus.*, V, 1:324 (synonymy).

Comparative proportions.—A specimen, *Ls* 152.0, *Lt* 189.5, caught in the Tamar estuary off Lagoon Bay, Low Head, Dorset, in green seaweed, at 3-4 fathoms by Mr R. Askeland in January 1962, affording the first Tasmanian record of this species, has been noticed in these Observations, and a table of proportions, as thousandths of total length, provided (Scott, 1964:98). For convenient comparison with other members of the family considered in the present contribution, the available relevant proportions have been recalculated as thousandths of standard length and incorporated in Table V.

NEOODAX BALTEATUS (Cuvier & Valenciennes), 1839

Odax balteatus Cuvier & Valenciennes, 1839, Hist. Nat. Poiss., xiv: 303. Type locality: none recorded (Péron [= Tasmania (McCulloch, 1929: 324)].

TABLE V

Haletta semifasciata (Cuvier & Valenciennes), 1840, *Neoodax frenatus* (Günther), 1862, *N. balteatus* (Cuvier & Valenciennes), 1839, *N. radiatus* (Quoy & Gaimard), 1835. Some proportions, as thousandths of standard length, of Tasmanian specimens: for exact localities see text

Dimension	*Haletta semifasciata*		*Neoodax frenatus*	*Neoodax balteatus*			*Neoodax radiatus*
	(*a*) *Ls* 253.0	(*b*) *Ls* 321.0	*Ls* 152.2	(*a*) *Ls* 60.6	(*b*) *Ls* 73.1	(*c*) *Ls* 84.4	*Ls* 152.0
Total length	1174	1165	1271	1216	1211	1256	1240
Length to first dorsal origin	324	332	283	333	319	331	276
„ „ first dorsal termination (last spine)	635	620	624	640	630	615	..
„ „ second dorsal origin (first ray)	647	633	638	649	646	629	..
„ „ second dorsal termination	837	840	817	840	846	821	826
„ „ anal origin	648	651	650	613	612	629	628
„ „ anal termination	832	824	811	843	829	852	789
„ „ pectoral origin	279	276	257	281	274	267	263
„ „ pelvic origin	356	347	322	365	338	367	304
„ „ vent	636	636	624	591	590	603	622
Length of longes (*n*th) dorsal spine	83 (9th)	78 (12th, 15th)	106 (6th)	117 (11th)	124 (10th)	106 (11th)	189 (1st)
„ „ longest (*n*th) dorsal ray	109 (9th)	106 (8th)	102 (11th)	130 (11th)	109 (12th)	136 (12th)	112 (1st)
„ „ 1st anal spine	37	25	98	49	57	53	53
„ „ 2nd anal spine	72	55	91	67	85	95	86
„ „ 3rd anal spine	78	66	72	89	(none)	106	102
„ „ longest (*n*th) anal ray	94 (12th)	76 (9th)	72 (2nd,3rd)	97 (2nd)	93 (2nd,3rd)	108 (2nd)	..
„ „ pectoral (whole fin)	154	157	125	163	152	178	..
„ „ longest (*n*th) pectoral ray	126 (7th,8th)	126 (5th,6th,7th)	112 (4th)	137 (8th)	136 (7th)	150 (7th)	112 (4th)
„ „ pelvic (whole fin)	125	112	174	134	135	158	..
„ „ pelvic spine	88	83	137	99	109	120	..
„ „ 1st pelvic ray	109	100	171	119	115	132	..
„ „ 2nd pelvic ray	115	103	129	122	122	136	..
„ „ 3rd pelvic ray	106	97	98	102	118	119	..
„ „ 4th pelvic ray	69	83	86	87	98	100	..
Head, with opercular flap	279	280	279	302	309	310	283
„ without opercular flap	265	269	265	267	274	284	260
Mouth	59	69	75	58	56	63	..
Eye	44	44	51	81	68	71	47
Snout	118	118	104	87	95	101	106
Interorbital, soft	55	67	49	83	79	55	84
„ bony	48	62	47	66	56	47	..
Depth, maximum	206	196	181	180	192	191	172
„ at opercular border	174	184	157	165	168	187	168
„ at vent	186	181	154	165	178	169	164
„ at caudal peduncle (minimum)	87	87	52	106	109	107	92

Odax algensis Richardson, 1840, *Proc. Zool. Soc. London*: 26. Type locality: Port Arthur [Pembroke], Tasmania.

Odax brunneus Macleay, 1881, *Proc. Linn. Soc. N.S.W.*, vi, 1: 109. Type locality: Port Jackson [New South Wales].

Material.—Three small examples collected by Mr B. C. Mollison: (*a*), *Ls* 60.6, *Lt* 73.7, (*b*) *Ls* 73.1, *Lt* 88.5, both taken at Middleton, Buckingham on 25th June 1961 in 6-10 fathoms; (*c*), *Ls* 84.4, *Lt* 106.1, from Woody Island, Buckingham, on 6th June 1963.

Proportions.—For some proportions, as *TLs*, see Table V.

Meristic data.—D xv, 13; xvi, 12; xvi, 12. A. iii, 12 (last cleft to base); iii, 13 (last cleft to base); iii, 13. P. 14, 14; 13 (left), 14; 13 left), 14. V. i, 4. C. 12 main, 16 total, rays. L. lat. 38, 38, 37. L. tr. 4/12, 4/13, 4/14.

For his *Odax algensis*, which has Port Arthur [Pembroke] Tasmania as type locality, and which since Günther (1862: 240) has been regarded as synonymic with Cuvier & Valenciennes' species, Richardson (1840: 26)) reported only 2 anal spines (while for *O. brunneus* Macleay, regarded by McCulloch (1929: 324) as another synonym, the low total anal count of 14—spines and rays not being distinguished—may perhaps involve a reduction in number of spines). It is interesting therefore to note the position in the present material: in (*a*) and (*c*) the first anal spine is wholly bound up with the second, and it is only with some difficulty its presence is established, in (*b*) only 2 spines occur—however, the anterior shows some suggestion of division distally and may possibly result from the fusion of what would normally have been the first and second spines.

Remarks.—The scales on the preoperculum in advance of the ridge, which is well defined, are in 2-3 rows above and reach a maximum of about 5 below at about the level of hind border of pupil, in advance of which, reduced to 1-2 rows, they extend to below front of pupil, or beyond: they are subequal in size, very much smaller than those on operculum. The width of the naked ocular annulus ranges from one-eighth to one-quarter of a pupil-diameter: in (*a*) the pores occurring in this area

are associated with tubules, which from 8 o'clock (left side) extend forwards, as a continuous ridge, under the eye and well beyond level of its anterior margin. The genal facet, the degree of patency of which increases in the sample with size of fish, is, at its most pronounced, intermediate in development between that in *Haletta fasciata* and that in *Neoodax frenatus*, as represented by our material: its posterior tip reaches almost to below hind border of orbit. Preoperculum behind ridge naked, save for several small scales on left side of (*c*). Large or largish scales occur on the operculum (the upper ones slightly larger or slightly smaller than contiguous body scales, the lower regularly larger than those on pectoral base); they are disposed much as in *H. fasciata*. Suboperculum naked.

Scales on the dorsal surface of the head cease at, or (*c*) slightly in advance of, level of upper angle of preoperculum.

The whole vertical border of the preoperculum is denticulate; glassy projections basally contiguous, acute, 25-30.

Termination of mouth lies midway between tip of snout and eye between anterior orbit and front of pupil. As in *H. fasciata* and *N. frenatus* a subtriangular lobe lies between, and partly covers, the bases of the pelvics.

Specimen (*a*) has a whitish ovoid encysted parasite on the penultimate dorsal ray; (*b*) has one each on the second and the last 3 dorsal rays; (*c*) has two on caudal.

Coloration.—General color of specimens, as preserved in formalin, light, somewhat yellowish brown, darker on back and on side above midlateral line. Dark band, subequal in width to pupil, from upper lip horizontally to eye; behind eye continued (with some increase in width; most notable in (*c*), in which at its maximum extension, occurring near middle of fish, it doubles) straight to middle of caudal base. Indications of about 8 imperfect vertical bars, noticeably developed below the dark longitudinal band only in (*c*), in which irregular dark patches, each involving several scales, are obscurely continuous with, or separate from, rest of bar on upper half of side. Superoposterior surface of upper lip slate, or darker; rest of lip, and whole of lower lip, white. All fins white, except caudal of (*c*), which is yellowish brown basally, darkening somewhat distally.

Genus **HALETTA** Whitley, 1947

HALETTA SEMIFASCIATA (Cuvier & Valenciennes), [1840]

Odax semifasciatus Cuvier & Valenciennes, 1840, Hist. Nat. Poiss. XIV ['1839' = Jan. 1840, *fide* McCulloch, 1929:323]: 299, pl. ccccvii. Type locality: 'Mers des Indes' (Péron) [= Tasmania (McCulloch)].

Odax richardsonii Günther, 1862, Cat. Fish. Brit. Mus., IV:241. Type locality: Port Jackson, New South Wales, and Hobson's Bay, Victoria.

Odax hyrtlii Steindachner, 1866, *Sitzb. Akad. Wiss.* Wien, liii:464, pl. V, fig. 4 (teeth). Type locality: Port Jackson, New South Wales (Hyrtl).

Haletta semifasciata (Cuvier & Valenciennes). T. D. Scott, 1962, The Marine and Fresh Water Fishes of S. Aust.: 281, unnumbered fig. on p. 281.

Material.—Four examples in the Queen Victoria Museum, Launceston have been examined: (*a*) *Ls* 253.0, *Lt* 297.0; (*b*) *Ls* 321.0, *Lt* 374.0; (*c*) and (*d*), which have been gutted, have approximate standard lengths of 322, 326 and approximate total lengths of 373, 378, respectively. Specimen (*a*) Tamar River, Devon/Dorset on 28th July, 1965, E. W. Gatenby (Queen Victoria Museum Reg. No. 1965.5.7); (*b*) Beauty Point, Devon, on 20th August 1965, E. W. Gatenby (Q.V.M. Reg. No. 1965.5.11); (*c*) and (*d*) off mouth of Little Forester River, Dorset, in about 12 ft of water, on 10th September 1961, J. Waterhouse (Q.V.M. Reg. No. 1961.5.3).

Meristic data.—For his *Odax richardsonnii* Günther (1862) gave D. xvii, 13; A. iii, 11-12. T. D. Scott (1962: 281), while retaining the anal formula unchanged, admits variation in the dorsal specification thus, xvi-xvii, 13-14: earlier, however, Macleay (1881: 107), following Günther (1862: 241) had given for Cuvier & Valenciennes' species D 18/12, and had allowed only 2 anal spines (2/11). For the 4 Tasmanian examples we have these counts, D. xviii, 13; xviii, 13 (last cleft to base); xviii, 13; xvii, 14 (last half cleft). A. iii, 12; iii, 11 (last cleft to base); iii, 12; iii, 11. P. 15 in all except in left fin of (*d*), which has 14. V. i, 4 in all (Scott, who correctly notes 4 rays in his general description, has by inadvertence i, 5 in his formal meristic specifications). C. 12 main, 16 total, rays in all. L. lat. 62, 64, 66, 65. L. tr. 8/15, 8/16, 8/16, 8/17.

Proportions.—Some proportions of (*a*) and (*b*) are exhibited in Table V—(*c*) and (*d*) gutted—for comparison with those of three other species.

Remarks.—Scales on the preoperculum in advance of the ridge (which is much less developed than in *Neoodax frenatus*, being in parts obsolescent) form an arc, 5-6 rows wide above and below and 3-4 rows in the middle one-third of band, extending between levels of upper border and middle of lower border of orbit: they are subequal in size, decidedly smaller than those on operculum. Separating this series of scales from the eye is an arc of smooth skin (perforated by portion of a semicircle of small pores concentric with back and lower part of orbit), its width subequal to diameter of pupil, or about one-third shortest distance between orbit and preopercular border: in *N. frenatus* it is relatively about half as wide. Preoperculum behind its ridge naked. The naked lanceolate genal facet noted above in *N. frenatus* is here much less conspicuous, being less acutely angled to the plane of the cheek immediately above it and being bordered superiorly by a less developed ridge: its posterior tip reaches only to midway between middle and hind border of pupil, instead of beyond orbit as in the other species. Large or largish scales occur on the operculum (the upper ones slightly larger or slightly smaller than contiguous body scales, the lower regularly larger than those on pectoral base); they do not extend below, if as far as, the horizontal level of the lower insertion of the pectoral lobe, and are usually absent also from a narrow slip (broadest below, where its width is about that of 2 scales) immediately behind the preoperculum, and,

briefly, from part of the upper half of the opercular margin. Subopercular naked.

A marked difference in the disposition of scales on the dorsal surface of the head characterizes *H. fasciata* and *N. frenatus*: in the former scales continued from the body cease at about the level of the end of the preopercular, roughly an eye-diameter behind level of eye; in the latter they extend forwards to, or a trifle beyond, level of front of eye.

In (*a*) the preopercular border is clearly crenulate, and conspicuously, though rather minutely, denticulate: in the other examples the crenulation is more obscure and the amount of the denticulation much reduced.

In this species the termination of the mouth lies midway between tip of snout and a point between front of eye and anterior half of pupil: in our specimen of *N. frenatus* twice horizontal mouth-length reaches just beyond eye.

Six ovoid whitish cysts, 1.5-2 mm long, occur on the caudal rays of (*b*).

Coloration. This exhibits considerable variation; as is illustrated by the following brief specifications of (*a*) and (*b*).

(*a*) General color above dusky with some slate grey on side. Most scales predominantly golden, bordered behind by blue and with some silver in front: in parts, gold reduced to inframarginal arc adjoining blue: in advance of tip of adpressed pectoral, upper flank with most scales wholly silver and marginal blue. On lower half of most of side blue so disposed as to give rise to 3 or 4 longitudinal lines. Ventral surface wholly silvery. Head with scaled areas silvery, with much blue (some scales blue only); dorsum very dark green; snout above level of bottom of eye greenish, translucent, below this more or less silvery. Whitish annulus round eye; iris greenish gold with red lustres, ringed externally with peacock blue; pupil blackish. Spinous dorsal: spines broadly bordered green; membrane in general translucent, somewhat dusky distally, with blue splashes and spots (especially in outer half), and with red and orange splashes along base. Soft dorsal: rays with distal half mostly dull amber, proximal half cross-banded red-blue-red-blue-red; some black at bases of first 7 rays (also, in first 3-4, black along length of rays). Anal: rays mostly whitish or silvery, becoming dusky distally; membrane silvery at base, elsewhere chiefly greyish, with blue and red splashes in basal one-third, or, anteriorly, in basal half, the red in particular tending to form a horizontal line. Pectoral: membrane silvery white; rays straw, very slenderly outlined in red. Pelvic: spine, rays and membrane silvery. Caudal: membrane partly silvery, partly bluish; rays with basal half, or more, reddish on silver, the free silver becoming dark greyish or blackish towards the tips.

(*b*). Trunk and tail: very dark greenish brown on back and upper one-fourth of flank; then becoming largely greenish, the scales edged in their anterior half or one-third with warm red-brown; most of rest of flank ranging from color just described to silvery, marked with 6-8 pinkish or pink and gold (behind level of vent increasingly golden) lines; towards ventral profile free of these lines and with ground colour continuous with that of the ventral surface, which is silvery up to vent, caudad of which it becomes increasingly golden. About 10 irregularly shaped, and in parts (particularly above) obscurely delimited, vertical dark olive brown bars running from dorsal profile from two-thirds to three-fourths of distance towards ventral profile, the first mainly cephalad of dorsal origin, the last on caudal base. Three short light green bars diverging forward from vent. Head: dorsum dark, somewhat greenish brown; snout down to level of lower border of eye concolorous with dorsum, below this with some green and silver; subvertical band of scales on preoperculum bright green, rest of vertical limb of preoperculum shining green and reddish, subhorizontal limb mostly silver; squamous portion of operculum green (darker than scaled preoperculum), rest silvery gold; subopercular silver; lower lip yellowish flesh, upper dark greenish brown. Spinous dorsal: spines reddish green, barred green-red basally; membrane translucent, with faint pinkish, purplish and greenish flushes, most pronounced adjoining the spines, and with some purple round spine-bases. Soft dorsal: rays olivaceous, becoming more or less amber distally; membrane resembling that of first dorsal, but less extensively colored. Anal: rays pink; membrane immaculate, translucent silvery white. Pectoral: membrane translucent, immaculate; rays somewhat greenish amber. Pelvic: membrane completely translucent; spine and rays white. Caudal membrane flesh-colored, with greenish tinge and some reddish lights; rays greenish brown.

Family Clinidae

The five species then recorded from Tasmania, (together with two—*Tripterygion clarkei* Morton, 1888, *Gillias macleayanus* (Lucas), 1891— now segregated in the family Tripterygiidae) were keyed in Part VII of these Observations (1955: 137): a sixth, *Petraïtes heptaeolus* Ogilby, 1885, has since been listed (1965: 59). Another species of *Petraïtes* Ogilby, 1885, *P. phillipi* (Lucas), 1891, previously reported (McCulloch, 1929: 349) only from Victoria, and a second species of *Cristiceps* Cuvier & Valenciennes, 1836, *C. argyropleura* Kner, 1865, recorded in the Check-List (McCulloch, 1929: 350) only from New South Wales and Lord Howe Island, are here added to the local list, which thus stands at eight.

Some general observations are made on *Clinus perspicillatus* Cuvier & Valenciennes, 1836, *C. puellarum* Scott, 1935, *Petraïtes heptaeolus* Ogilby, 1885. Ocular and rostral tentacles—features of which little use has hitherto been made in specific diagnoses, but which appear to be of considerable taxonomic importance—are figured (fig. 1, *a-h*) for the locally occurring clinids; comprising, in addition to the 3 species named above in this paragraph, *Petraïtes phillipi, P. johnstoni, P. forsteri, Cristiceps australis, C. argyropleura.*

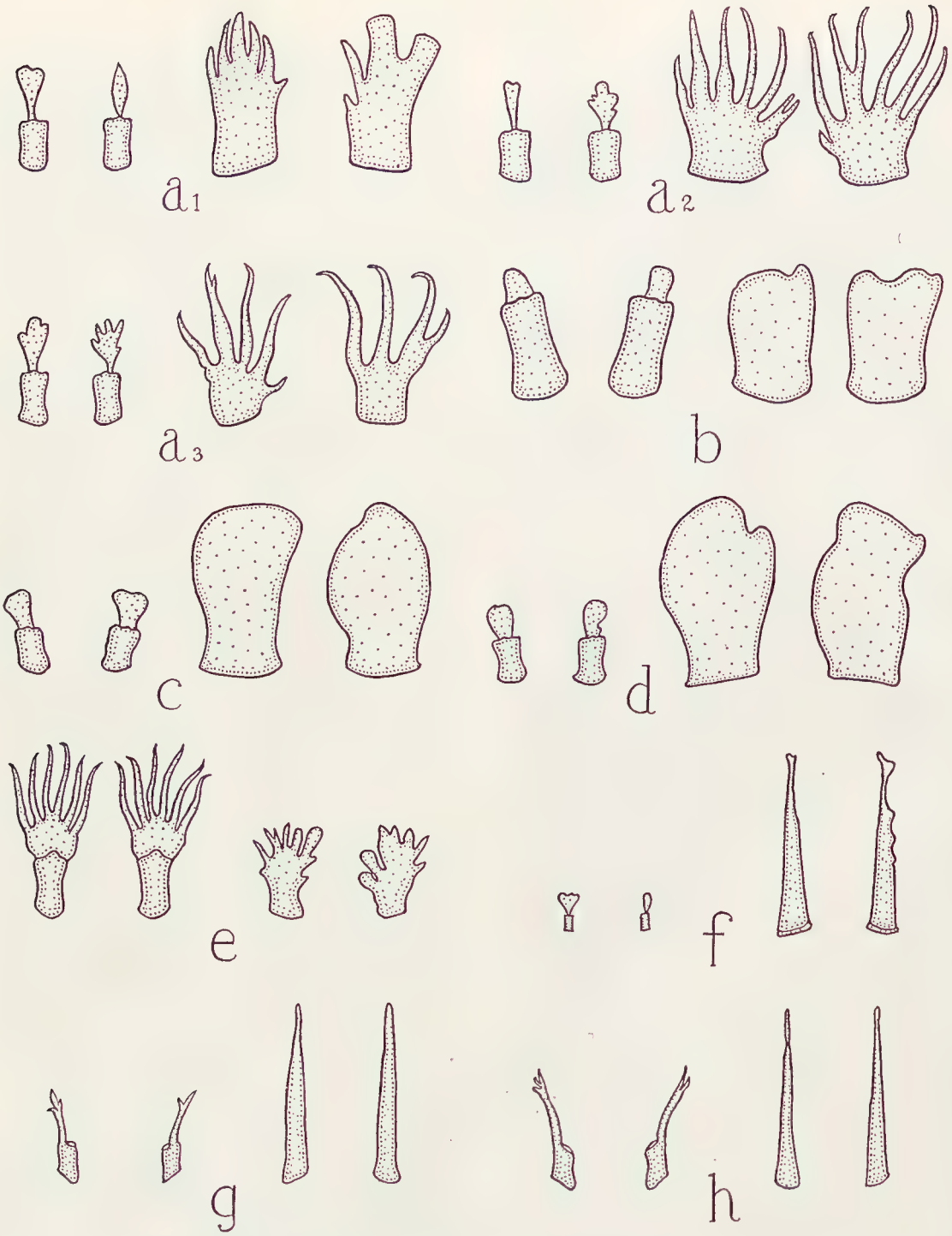

FIG. 1.—ROSTRAL AND OCULAR TENTACLES OF TASMANIAN CLINIDS

For each specimen there are shown, in succession from the left: right rostral, left rostral, right ocular, left ocular tentacle; all viewed from in front. Pigmentation not indicated. Standard length of fish (*Ls*) in millimetres.

a.—Clinus perspicillatus Cuvier & Valenciennes, 1836: a_1 *Ls* 38.0, × 15; a_2 *Ls* 69.0 × 11; a_3 *Ls* 111.2 × 8½. *b.—Clinus puellarum* Scott, 1955: *Ls* 35.7, × 45. *c.—Petraïtes heptaeolus* Ogilby, 1885: *Ls* 44.7, × 25. *d.—Petraïtes phillipi* (Lucas), 1891: *Ls* 78.2, × 15. *e.—Petraïtes johnstoni* (Saville-Kent), 1886: *Ls* 95.0, × 4½ (the rostral tentacles are in preserved specimens constantly directed forwards; they have been lifted and drawn as if carried erect). *f.—Petraïtes forsteri* (Castelnau), 1872: *Ls* 88.8, × 4. *g.—Cristiceps argyropluera* Kner, 1865: *Ls* 70.5, × 9. *h.—Cristiceps australis* Cuvier & Valenciennes, 1836: *Ls* 80.0, × 5.

Genus **CLINUS** Cuvier, 1816

CLINUS PERSPICILLATUS Cuvier & Valenciennes, 1836

(Fig. 1 *a*)

Clinus perspicillatus Cuvier & Valenciennes, 1836, Hist. Nat. Poiss., XI: 372. Type locality: Westernport, Victoria (Quoy & Gaimard).

Clinus despicillatus Richardson, 1839, *Proc. Zool. Soc. Lond.*: 97. Type locality: Port Arthur, Tasmania.

Material.—(*a*) 11 specimens from Taroona, Buckingham, earlier discussed in the Observations (1965: 60): this series has *Ls* range 31.0-137.8 $\bar{x} = 97.88 \pm 8.74$, $\sigma = 29.00 \pm 6.18$, $V = 29.6 \pm 6.2$; *Lt* range 36.1-156.7, $\bar{x} = 112.85 \pm 9.93$, $\sigma = 32.93 \pm 7.02$, $V = 29.2 \pm 6.72$. (*b*) a pooled sample of 29 specimens from Green's Beach, Devon, collected by Mr R. H. Green (*Ls* 24.4-113.5, $\bar{x} = 56.60 \pm 5.58$, $\sigma = 30.06 \pm 3.95$, $V = 53.1 \pm 8.2$; *Lt* 28.8-130.0, $\bar{x} = 65.96 \pm 6.14$, $\sigma = 33.07 \pm 4.34$, $V = 50.1 \pm 6.60$), comprising 3 subsets: (*i*) 6 specimens, 27th September 1964 (*Ls* 70.0-109.0, $\bar{x} = 93.08 \pm 5.46$, $\sigma = 13.38 \pm 3.86$, $V = 14.37 \pm 4.15$; *Lt* 82.2-124.9, $\bar{x} = 107.90 \pm 5.93$, $\sigma = 14.55 \pm 4.20$, $V = 13.49 \pm 3.89$); (*ii*) 17 specimens, 14th December, 1964 (*Ls* 24.4-51.05, $\bar{x} = 34.66 \pm 1.56$, $\sigma = 6.45 \pm 1.11$, $V = 18.61 \pm 3.30$; *Lt* 28.8-59.4, $\bar{x} = 40.77 \pm 1.79$, $\sigma = 7.38 \pm 1.27$, $V = 18.10 \pm 3.20$); (*iii*) 6 specimens, undated (*Ls* 54.4-113.5, $\bar{x} = 82.26 \pm 10.20$, $\sigma = 26.84 \pm 7.75$, $V = 32.62 \pm 10.37$; *Lt* 63.2-130.0, $\bar{x} = 95.38 \pm 9.21$, $\sigma = 22.55 \pm 6.51$, $V = 23.63 \pm 7.19$).

Subset (i) is associated with 1 *Petraïtes heptaeolus;* subset (*ii*) with 44 *Bovichtus variegatus,* 5 *Pictiblennius tasmanianus,* 5 *Alabes rufus,* 1 *Clinus puellarum,* 2 *Petraïtes heptaeolus;* subset (*iii*) with 7 *Pictiblennius tasmanianus,* 3 *Petraïtes phillipi,* 1 *Cristiceps argyropleura,* 1 *Callogobius hasseltii.*

Dorsal and anal counts.—Recorded ranges for dorsal and anal formulae are: D. iii, xxxii-xxxiv, 3-5. A. ii, 23-26. The anal minimum, 2 lower than previously recorded, was reported (1965: 60) for one individual of the Taroona sample. Counts of the pooled Green's Beach material extend, by 1 at each extreme, the range of spines in the second dorsal, which now becomes xxxi-xxxv.

Dorsal and anal patterns.—Pooling of the Taroona and Green's Beach material yields the 12 patterns of total dorsal radial elements (spines plus soft rays) set out in Table VI: no doubt some, if not all, of the obvious combinations unrepresented here (*e.g.,* iii, xxxiv, 3) would be met with in longer series. Inspection of Table VI makes evident the occurrence of a higher mean number of dorsal elements in the Taroona fish. This point is more formally investigated in the frequency distribution exhibited in Table VII; which records also total anal radial elements (spines constantly ii).

In the absence of a larger southern sample it is not clear whether the highly significant differences between the northern and southern populations of dorsal spines and total dorsal elements recorded in the table are to be attributed, wholly or partly, to locality or to some other factors or factors. Increase in the number of rays, *sensu lato,* with increase in size of fish is met with in some blennoid and clinoid species. No certain association of this kind characterizes the present material. Calculation of correlation coefficients for standard length and total dorsal radial elements for the Taroona sample (11 specimens), the pooled Green's Beach material (29) and the largest Green's Beach subset (17) yields two non-significant correlations—one negative (possibly a sampling phenomenon) and one positive—and one positive correlation significant at the 5% level; the respective values being $r = -0.45$, $z = 0.49$, $t = 1.53$; $r = +0.31$, $z = 0.30$, $t = 2.21^*$; $r = +0.22$, $z = 0.22$, $t = 0.65$.

Tentacles.—In his survey of common Australian clinids McCulloch (1908: 43) says of the present species, 'A slender branched tentacle on the snout and another large one over the eye'; T. D. Scott (1962: 253) has 'A small, simple tentacle over the eye, and a slender branched tentacle on the snout'. Neither specification fits the present material, in which the position is as follows. The rostral tentacle invariably consists of a fleshy cylinder, surmounted by a single flap arising from the posterior aspect of its free rim: generally this lamella is simple and more or less ovate or lanceolate; in large individuals, of *Lt* 120 or more, its upper border may develop one or several incisions, resulting in its becoming crenulate—the incisions, however, are always shallow, the terminal or laterotermínal lobes remaining short, wider than, or as wide as, long; in striking contrast to the digitform lobes of the larger ocular tentacle. The latter regularly presents, in fish of all sizes, a more or less hand-like structure, with, usually 3-5, finger-like diverging lobes, the region corresponding to the palm not being as high as, usually much lower than, the longest (commonly the median) fingers. Characteristic tentacles are shown in fig. 1 *a*.

CLINUS PUELLARUM Scott, 1955

(Fig. 1 *b*)

Clinus marmoratus Klunzinger, 1872, *Arch. Naturg.,* xxxviii, 1: 33. Type locality: Port Phillip, Victoria. Preoccupied by *Clinus marmoratus* Castelnau, 1861, Mem. Poiss. Afr. Austr.: 52 (Table Cape, South Africa).

Clinus puellarum Scott, 1955, *Pap. Proc. Roy. Soc. Tasm.,* 89: 139, pl. 1, fig. 1. Type locality: East Beach, Low Head [Dorset], Tasmania.

Clinus marmoratus Klunzinger. Whitley, 1941, *Aust. Zool.,* 10, 1: 38, fig. 25 (lectotype).

Clinus puellarum Scott. Whitley, 1956, *Aust. Zool.,* xii, 3: 261 (synonymy).

Status.—The original account of *Clinus puellarum* noted 'The description of *C. marmoratus* is not sufficiently detailed or precise to permit of its unequivocal recognition. *C. puellarum* appears to differ from it chiefly in exhibiting the following features: larger head, shallower body; earlier origin of dorsal (?); color pattern, especially absence of dark spots and presence of light patches; lesser size'. Whitley, who examined the two types of Klunzinger's species in Stuttgart, has given a description and figure (1941: 38, fig. 25) of the larger, *Lt* 144, which he has selected as lectotype: subsequently (1956: 261) he has identified *C.*

TABLE VI

Clinus perspicillatus Cuvier and Valenciennes, 1836. Frequency distribution of dorsal spines (both fins), of total dorsal radial elements (spines plus rays), and of total anal radial elements in two Tasmanian samples: 11 specimens, *Ls* 31.0–137.8, $\bar{x}$ 97.88 ± 8.74 mm, from Taroona, Buckingham; 29 specimens, *Ls* 24.4–113.5, $\bar{x}$ 56.60 ± 5.58 mm, from Green's Beach, Devon

Meristic feature	Locality	Frequency distribution					$\bar{x}$	σ	*V*	Significance of difference of means; *t*
Dorsal spines (both fins)		**34**	**35**	**36**	**37**	**38**				3.39**
	Taroona	..	2	5	3	1	36.27 ± 0.22	0.86 ± 0.18	2.4 ± 0.51	
	Green's Beach	2	15	11	1	..	35.38 ± 0.10	0.53 ± 0.07	1.5 ± 0.20	
Total dorsal radial elements		**38**	**39**	**40**	**41**	**42**				4.16**
	Taroona	..	..	7	2	2	40.55 ± 0.24	0.78 ± 0.17	1.9 ± 0.41	
	Green's Beach	4	13	10	2	..	39.34 ± 0.15	0.80 ± 0.11	2.3 ± 0.27	
Total anal radial elements		**23**	**24**	**25**	**26**	**27**				0.94
	Taroona	1	..	1	3	6	26.18 ± 0.36	1.19 ± 0.25	4.6 ± 0.97	
	Green's Beach	..	..	4	23	2	25.93 ± 0.03	0.14 ± 0.02	0.5 ± 0.07	

TABLE VII

Clinus perspicillatus Cuvier & Valenciennes, 1836. Dorsal radial element pattern in two Tasmanian samples: 11 specimens, *Ls* 31.0–137.8, $\bar{x}$ 97.88 ± 8.74 mm, from Taroona, Buckingham: 29, *Ls* 24.4–113.5, $\bar{x}$ 56.60 ± 5.58 mm, from Green's Beach, Devon, Tasmania

Pattern	Frequency	
	Taroona	Green's Beach
iii, xxxi, 4		1
iii, xxxi, 5		1
ii, xxxii, 3		2
iii, xxxii, 4		11
iii, xxxii, 5	2	2
iii, xxxiii, 2		1
iii, xxxiii, 3		1
iii, xxxiii, 4	5	8
iii, xxxiii, 5		1
iii, xxxiv, 4	2	1
iii, xxxiv, 5	1	
iii, xxxv, 4	1	

marmoratus with *C. puellarum*, but has pointed out Klunzinger's name is preoccupied [as above], so *C. puellarum* stands. Whitley's valuable description and illustration of *C. marmoratus* leave little doubt *C. puellaram* is conspecific.

Material.—The species, the known range of which now becomes Tasmania and Victoria, is apparently not common, examination of many hundreds of fish from Tasmanian rock-pools in the ten years since its description as *C. puellarum* having yielded only a single example: this is a male, *Ls* 35.7, *Lt* 41.0, taken at Low Head by Mr R. H. Green on 14th December 1964 [for associated species see under *Clinus perspicillatus*, above; series (*b*), subset (*ii*)].

General facies.—The original account of *C. puellarum* is a tolerably full one and does not seem to call for any supplementary detail. However, several general features deserve notice.

The species has a very characteristic form, departing noticeably from the overall configuration of *C. perspicillatus*, and in several ways approaching an ophiclinid facies as typified by, say, *O. gracilis* Waite, 1906—for a close relative of which it could on casual examination readily be mistaken (but from which it is immediately separable by the presence of an ocular tentacle). A striking feature is the almost rectilinear external border of the dorsal fin (discounting the 5-6 posterior rays and, in the present example, several early spines): this is clearly depicted in the figure (1955, pl.V, fig. 1) of the holotype of *C. puellarum*, and is also quite evident in Whitley's figure (1941, fig. 25) of the lectotype of *C. marmoratus*. This condition is in noticeable contrast to the convexity of the border in *C. perspicillatus*, and also in the well-characterized species of *Petraïtes*: the almost straight border of the spinous portion of the second dorsal in *Cristiceps* differs from that found here in that, instead of being about parallel to a line joining upper border of eye and middle of caudal peduncle, it slopes well downward towards the latter point. The Tasmanian specimens (though seemingly not the lectotype) present a closer approach towards parallelism of the dorsal and ventral body contours, particularly in the region immediately behind the vent, than is found in *C. perspicillatus* (or, indeed, in any common Australian clinid). The Green's Beach individual, and, as far as can be estimated in view of the distal upturning of the trunk, also the holotype from Low Head (the two localities are close together, lying on either side of the estuary of the Tamar), have the opisthion posturanic (*cf* Gregory, 1928): in *C. perspicillatus* the opisthion

may be preuranic, uranic, or posturanic; if the last-named, tending to be less markedly so than in *C. puellarum*. (The variability of this feature arises largely from difference in relative depth of trunk associated with overall size of fish, and, more markedly, from variation in the conformation of the sexes).

An interesting index is provided by the ratio of the anal base to the depth at vent. In *C. puellarum* the value exceeds 3 (present specimen 3.3, holotype 3.2); in *C. perspicillatus* it is usually less than, rarely equal to, 3 (for the 17 specimens specified in the general treatment of this species above as series (*b*), subset (*ii*) we find range 2.2-30, $\bar{x} = 2.60 \pm 5.67$; $\sigma = 23.6 \pm 4.05$; $V = 9.08 \pm 1.57$; the variates being approximately normally distributed): in the 3 specimens of *Ophiclinus greeni* Scott, 1936 noted in Part XII (1965: 62) this value is 4.1, 4.5, 4.5. In the two clinids the difference in magnitude of the ratio is in part accounted for by the occurrence in *C. puellarum* of a somewhat longer anal—its base, as *TLs*, being 549 in the Green's Beach specimen, 555 in the holotype, compared with, in the sample of 17 *Clinus perspicillatus* mentioned above, a range of 436-523, and a mean of 486.47 ± 5.41 ($\sigma = 22.52 \pm 3.86$, $V = 4.63 \pm 0.794$): in the same 3 *Ophiclinus greeni* anal base as *TLs* is 530, 551, 549.

Other features in which the Green's Beach fish shows at once a departure from *C. perspicillatus* and a measure of parallelism with *O. gracilis* (and *O. greeni*) are, first, the density of the pigmentation, particularly on the dorsal and anal, and, secondly, the opaque, somewhat velvety nature of the membrane of those fins (in the case of the dorsal, especially in its hinder portion).

Fin counts.—D. iii, xxxvii, 6. A. ii, 29. P. 13 (both fins). C. 13 (of which 10 reach hind border). This gives for the second dorsal one more ray than in the holotype and two more spines and one more ray than in the single paratype. Whitley, who does not recognize any distinction between spines and rays in the vertical fins, gives for the types of *C. marmoratus* examined by him at Stuttgart D. 44; A. 30; P. 13; C. 10. The reference in the account of *C. puellarum* (1955: 139) to a hidden spine in the pelvic appears to be an error.

Lateral line.—For the type material of *C. puellarum* this is described as comprising 'a short conspicuous earlier superolateral segment and a long inconspicuous later mediolateral segment'. The anterior segment, a flat arc above pectoral, consists of 24-25 perforated tubercles, the posterior, of more or less simple pores, is made up of an oblique set of 4 followed by a subhorizontal series of about 38, the last, approaching caudal base, very small. Whitley observes, 'Lateral line showing only anteriorly; it runs straight to the point of the pectorals, when it tends to drop downwards but soon vanishes. It is formed of closely arranged longitudinal keels'. In the Green's Beach fish the elevated anterior segment alone is readily seen; examination with a lens, however, reveals the presence of some irregularly spaced pores presenting an interrupted line along the middle of the flank.

Dimensions and proportions.—Measurements, in mm, of the present specimen for those dimensions recorded in the 1955 account follow (with, in parentheses, values, as *TLs*, for this fish and for the holotype). Head to end of operculum 8.3 (232, 235), to end of opercular flap 8.8 (246, 256). Eye 2.3 (64, 58); interorbital 1.25 (38, 38). Snout with upper lip 1.25 (35, 48), without upper lip 1.0 (28, 35). Length to middle of vent 13.6 (381, 406). Depth [and, in brackets, width] at points specified: front of eye 2.9 (81, 88) [29 (81, 85)], origin of dorsal 6.0 (168, 154), [3.8 (106, 138], immediately behind pectoral base 6.0 (168, 154) [4.0 (112, 106)], vent 5.9 (165, 167) [3.3 (137, 165)]: maximum depth 6.6 (185, 171). Depth of caudal peduncle 2.5 (70, 58). Dorsal: lengths to origin, termination 4.9 (137, 165), 35.0 (980, 1008); base of first dorsal 1.2 (34, 33), interdorsal 1.0 (28, 23), base of second dorsal 27.9 (781, 787); lengths of 1st, 2nd, 3rd spines of first dorsal 1.95, 2.1, 1.95 (55, 59, 55; 44, 48, 42), of 1st, 2nd, 3rd, 17th, 37th spines of second dorsal 2.0, 2.0, 2.1, 2.5, 3.0 (56, 56, 59, 70, 84; 46, 46, 47, 61, 83); radial interspaces of first dorsal 0.4, 0.7 (11, 20; 12, 18) first radial interspace of second dorsal 0.7 (20, 17); oblique heights of 1st, 3rd, 5th, 6th rays 4.0, 4.0, 3.8, 3.0 (112, 112, 106, 84; 112, 113, 77,—). Anal: lengths to origin, termination 14.5 (406, 417), 34.1 (955, 960); lengths of 2nd spine, 5th ray, 25th ray 1.8, 2.6, 3.2 (50, 73, 90; 58, 81, 92). Pectoral: length to origin 8.0 (224, 229); longest (6th, 6th) ray 5.3 (148, 117). Ventral: length to insertion 6.1 (171, 156); lengths of 1st, 2nd, 3rd rays 1.5, 3.9, 4.1 (42, 109, 114; 31, 117, 158). Longest caudal ray 5.3 (148, 142).

Coloration.—General color of lateral surface of trunk and tail somewhat yellowish green, heavily clouded on most of the trunk, distally on the tail, and along the whole dorsal profile with very dark, almost black chromatophores; the six irregular lighter regions previously described (1955: 143) are here not apparent. Ventral surface of trunk lightish yellowish green with scattered dark chromatophores. Head with dorsal surface dark; lateral surface largely greenish and greyish, with two dark ocular spokes as described for the holotype, and with a diffuse dark patch on the operculum not previously reported; ventral surface greenish with some dark brown; upper lip almost black to as far back as the expanded plate of the maxilla, which is grey; lower lip dark almost to its termination. Rostral and ocular tentacles more or less hyaline with some minute dark punctulation. Anterior two-thirds of combined dorsal with five irregular pale greyish translucent areas separated by very dark grey; posterior one-third opaque, blackish: all spines and rays tipped with white. Anal very dark brown, with a few small lighter patches anteriorly; spines and rays conspicuously white-tipped. Caudal largely dark grey, in parts blackish; ray-tips white: the basal white spot figured for the holotype is represented by a pale dot about 0.1 mm in diameter.

The holotype, paratype and present specimen exhibit considerable variation in coloration: this is partly dependent on the degree of expansion of the chromatophores. The white tips of the spines and rays of the vertical fins are highly characteristic. Whitley noted that Klunzinger's speci-

mens, after nearly seventy years in alcohol, are almost uniform brown, but show indications of dark brown margins to dorsal and anal and of light spaces at intervals along the former and on its last ray.

Tentacles.—These have been fully described in the account of the holotype (1955: 140, 141): tentacles of the present specimen are here figured (fig. 1 *b*).

Genus **PETRAITES** Ogilby, 1885

PETRAÏTES HEPTAEOLUS Ogilby, 1885

(Fig. 1 *c*)

Petraïtes heptaelus Ogilby, 1885, *Proc. Linn. Soc. N.S.W.*, x: 225 [as *nom. nud.* on p. 10]. Type locality: Port Jackson [New South Wales].

Cristiceps wilsoni Lucas, 1890, *Proc. Roy. Soc. Vict.* (n.s), iii: 10, pl. iii, fig. 1. Type locality: Port Phillip, Victoria.

Material.—The first record for Tasmania, in these Observations (1965: 59), was based on 2 specimens, *Ls* 44.7, *Lt* 53.9, *Ls* 50.1, *Lt* 60.2, from Green's Beach, Devon. Three further examples—(*a*) ♀, *Ls* 15.0, *Lt* 17.6, (*b*) ♂, *Ls* 45.6, *Lt* 54.1, (*c*) ♀, *Ls* 55.5, *Lt* 65.0—secured at the same locality by Mr R. H. Green exhibit some variations in fin counts and proportions. For data on other species collected at the same time as the present 3 specimens see above, in notes on *Clinus perspicillatus* [(*b*) with series (*b*), subset (*i*), (*a*) and (*c*) with series (*b*), subset (*ii*)].

Fin counts.—D. iii, xxxvii, 1 + 2 [(*a*), (*c*)]; iii, xxxviii, 1 + 2 [(*b*)]. A. ii, 20. P. 12. V. 3. C. 10.

Ranges for spines of the second dorsal now reported from 3 States become: Victoria (Lucas, 1890) xxxiv-xxxviii, New South Wales (McCulloch, 1908) xxxv-xxxvii, Tasmania xxxvi-xxxviii; and ranges for anal rays 17-21, 17-20, 20-21.

Proportions.—For the ratios recorded in Part XIII the values for the 3 present specimens and the 2 examples there discussed are as follows, the fish being in ascending order of *Ls* (in parentheses Ogilby's values for his type 3⅛ inches in length). Head 3.6, 4.1, 4.6, 4.1., 4.9 (5.2); caudal 6.8, 5.9, 6.4, 6.0, 6.8 (6.6); height 5.9, 4.1, 4.5, 4.1, 4.5 (4.6); length to vent 2.5, 2.8, 2.8, 2.8, 2.6 (—): in total length. Eye 3.4, 4.4, 3.5, 4.5, 3.4 (3.8); pectoral 1.8, 1.3, 1.4, 1.4, 1.5 (1.4); ventral 2.1, 1.6, 1.8, 1.7, 1.7 (1.4): in head. Snout 0.7, 0.6, 0.6, 0.6, 0.6, (half) eye; or 5.0, 7.3, 5.9, 7.5, 6.1 (about 7.2) in head. Interorbital 0.7, 0.6, 0.6, 0.6, 0.5 (0.4) eye. Middle spine of first dorsal 6.2, 1.9, 2.9, 2.1, 2.6 (—); longest (last) spine of second dorsal 3.5, 1.9, 2.0, 1.8, 1.8 (—); longest (antepenultimate) anal ray 4.1, 1.9, 2.3, 1.9, 2.2 (—): in head. The relatively small size of the fins in the smallest individual (*Ls* 15.0) is noteworthy, the entries for the listed spines and rays of the vertical fins being particularly striking. No clear indications of other correlations of magnitude of ratio with overall size of fish emerge.

Young, ova.—Specimen (*c*) is parous, having on each side of the abdominal cavity an ellipsoidal mass of young and ova enclosed in a common membrane. The right ovarian mass is 13 mm long, 7 deep, 4 wide; the left, not dissected out, appears slightly smaller. The right contains 212 eyed embryos, of modal diameter 800-1000μ, 165 ova with a mean diameter of about 500μ, and a large, undetermined number of smaller ova of varying size, ranging down to under 100μ.

Tentacles.—These are figured in this contribution (fig. 1 *c*): they have been described in Part XIII (1965: 60).

PETRAÏTES PHILLIPI (Lucas), 1891

(Fig. 1 *d*)

Cristiceps phillipi Lucas, 1891, *Proc. Roy. Soc. Vict.* (n.s.), iii: 11, pl. iii, fig. 2. Type locality: Port Phillip, Victoria.

Petraïtes phillipi (Lucas). McCulloch, 1908, *Rec. Aust. Mus.*, vii, 1: 43, pl. x, fig. 3.

Record.—Three specimens, (*a*) *Ls* 40.5, *Lt* 49.0, (*b*) *Ls* 47.0, *Lt* 55.5, (*c*) *Ls* 51.6, *Lt* 61.7, occur in a small collection of rock-pool fishes made by Mr R. H. Green at Green's Beach, Devon [collection is specified above, under *Clinus perspicillatus*, as series (*b*), subset (*iii*)]: this constitutes the first record for this State, the species hitherto being reported (McCulloch, 1929: 349) only from Victoria.

Fin counts, branchiostegal rays.—D. iii, xxxi, 2; iii, xxxi, 2; iii, xxxii, 3. A. ii, 24 (all specimens). P. 11 (both fins, all specimens). V. 2. C. 11. Branchiostegal rays—not recorded by Lucas (1891) or McCulloch (1908)—number 6 in all specimens. For dorsal and anal of his figured specimen Lucas recorded 3/30/2, 2/23 and for a second specimen 3/30/3, 2/23, while McCulloch, reporting on 5 examples, gave ranges of D. iii, xxx-xxxii; 2-3, A. ii; 22-25.

Proportions, TLs.—Length to: first dorsal origin 212, 211, 192; second dorsal origin (base of first spine) 289, 305, 279; dorsal termination (membrane) 1012, 1003, 1013; anal origin 494, 505, 503; anal termination (membrane) 983, 958, 973. Length of: pectoral 227, 233, 194; pelvic 221, 232, 205. Head 294, 277, 289; eye 96, 92, 79; interorbital 37, 38, 41. Depth: maximum 222, 213, 252; at vent 175, 192, 215; of caudal peduncle 52, 51, 56. Total length 1210, 1182, 1196.

Remarks.—For his specimen (*a*) Lucas notes the 2nd spine ('ray') of the first dorsal as the longest, while simply observing of his (*b*) 'first and second rays much longer than the third'; McCulloch's figure shows 1st and 2nd spines subequal, about 1.8 times 3rd. The 2nd spine exceeds the 1st in all our fish, the 3rd being about two-thirds of the 2nd, and subequal to 1st of second dorsal, which is one-half, or less, the last spine. In (*a*) and (*b*) the 1st dorsal ray—damaged in (*c*)—is the longest, its tip projecting noticeably beyond that of the last spine. Anal rays increase more or less regularly to the penultimate. Outer pelvic ray ⅘-⅚ of inner; 7th pectoral ray longest. First segment of lateral line more or less horizontal (anterior half slightly convex upwards), with 20-22 tubules; an oblique line of 5-6 pores; third segment along midlateral line, pores, more widely separated and more difficult of detection posteriorly, about 30 or more. Mouth to below anterior border, or

first one-fifth, of eye (shorter than figured by Lucas or McCulloch).

Lucas describes his (*a*) as having 'supra-orbital and snout tentacles very short and small', and (*b*) as having 'supra-orbital tentacles aborted, and snout tentacles short, but distinct': McCulloch notes of both sets simply 'very small and simple'. The rostral tentacle is of the usual type, a cylinder from the hind rim of which arises a somewhat shorter process. The process is so borne that, viewed from the side, it presents an erect proconcave arc. The supraorbital tentacle is a simple rather broadly ovate, or panduriform, lobe; the distal margin entire or slightly crenulate. Figures of both tentacles are here provided (fig. 1 *d*).

Curiously enough, the simple outline figure accompanying the original description succeeds in conveying a much more satisfactory idea of the characteristic facies of the fish than the meticulous illustration provided in McCulloch's survey, which, while recording much more detail, fails to catch the curious triangular nature of the anterior outline and the acute posterior angle that together serve to distinguish at a glance this from the other common species of *Petraïtes*.

Sex.—Specimens (*a*), (*c*) are females carrying young, the eyes apparent through the body wall. The parous condition leads to more lateral than ventral distension, the greatest width of the trunk being more than twice that of the tail. Specimen (*b*) is probably a female also, presenting immediately in advance of origin of anal fin a circular opening, 1.9 in diameter, ringed with a low crenated wall, that presumably represents the distended genital aperture, through which young may have recently been extruded. The yellowish white combined ovarian mass and oviduct of (*c*) is 11 long, 5 wide, 6 deep. It contains 102 eyed ova, fairly tightly embedded, inside a common membrane, in a moderate amount of chiefly gelatinous stroma. Their size mostly ranges from 1.1 (more or less spherical) to 2.8 mm, the modal diameter being around 2. Development is rather more advanced than in the ova of *P. heptaeolus* noted above: in contrast to the position in the example of that species examined there are here no unfertilized ova.

Coloration.—For his (*a*) Lucas records merely 'colours ill-defined in a spirit specimen', but records for (*b*) 'Colour, few dark vertical bands; white band from eye across præoperculum and operculum, continuing along the trunk and tail, below the lateral line to the root of the caudal'. McCulloch has nothing on color in his text, but his illustration shows a pattern in general agreement with that traceable in our material. In our examples, preserved in formalin, the general color is purplish pink; head in general somewhat lighter, with in (*b*) some greyish; belly light purplish, immaculate. The dark pattern on body and tail is now indistinct, but appears to comprise about 6 irregular dark spots along dorsal profile, with one or two dark blotches below each, resulting in the formation of incomplete subvertical bars. A narrow light line runs the full length of the body, at the middle of the side, in (*a*) and (*b*), but is traceable backwards only about half that distance in (*c*): the extension forwards on to the head described by Lucas and indicated (in a slightly different arrangement) in McCulloch's figure is not apparent in the Tasmanian fish. Head with some darkish cloudings (regularly on upper half of operculum) and with some dark vermiculations, best developed on lips, suboperculum, and lower limb of preoperculum; a dark interorbital cross bar. Dark areas on the second dorsal fin, with in (*b*) and (*c*) one in the first dorsal, represent more or less regular extensions upwards from the dark spots fringing dorsal profile of body; rest of fin irregularly ashen and dusky. The anal, collapsed in all specimens, presents 6-7 well-marked blackish spots, which when the fin is erected are seen to constitute short dark bands running downwards and somewhat forwards across rays and membrane, as shown in McCulloch's figure. Pectoral pale grey or whitish; a little dark pigmentation proximally. Pelvic pale yellow, immaculate. Caudal rays crossed by up to 8 narrow dark bands.

Size.—With sexual maturity in the female at a total length of 49, or possibly less, it would seem probable this species does not reach any great size. Specimens described by Lucas measured 67, 53, the present examples are 49.0, 55.5, 61.7, while McCulloch's figure, noted as natural size, is 90. Relative size of sexes does not seem to have been investigated in Australian clinids: some incidental observations suggest a possibility that in *Clinus perspicillatus* males are larger. Of the Eastern Pacific Clinidae reviewed by him Hubbs (1952: 155) has noted 'Secondary sexual dimorphism is present in most, if not all of the species examined'.

PETRAÏTES JOHNSTONI (Saville-Kent), 1886

(Fig. 1 *e*)

Clinus johnstoni Saville-Kent, 1866.—*Rept Fish. Dept Tasm.*, 1866: 13. Type locality: Adventure Bay [Bruni Island, Buckingham], Tasmania.

Clinus johnstoni Saville-Kent. Saville-Kent, 1867, *Pap. Proc. Roy. Soc. Tasm.* (1866): xxxiv and 121. *Id.* Johnston, 1891, *Pap. Proc. Roy. Soc. Tasm.* (1890): 33. *Id.* McCulloch, 1915, *Proc. Linn. Soc. N.S.W.*, xl, 2: 273, pl. xxxvii, fig. 2. *Id.* Scott, 1935, *Pap. Proc. Roy. Soc. Tasm.* (1934):69.

Petraïtes johnstoni (Saville-Kent). Scott, 1955, *Pap. Proc. Roy. Soc. Tasm.*, 89: 138.

Generic status.—Reasons for referring this fish to *Petraïtes* Ogilby, 1885 are considered in an earlier contribution (1955: 139).

Previous descriptions.—Saville-Kent's description of the type, which was 'preserved alive for some time in the tanks of the fishery', merely notes that it belongs to the genus *Clinus*, and 'differs from the single species, *C. despicillatus* [*i.e.*, *C. despicillatus* Richardson, 1839 = *C. perspicillatus* Cuvier & Valenciennes, 1836] hitherto taken in these waters, and which averages the length of 4 or 5 inches only, in its larger dimensions, 15 inches, and in the great development of the nostril tentacles, and in other characters of specific value'. Johnston (1891: 33) recorded fin counts only, and the first full description and figure were supplied by

McCulloch (1915), whose account is based on 2 specimens, 227, 341 in total length, in the Australian Museum, though he remarks, 'I have also examined a still larger specimen in the Tasmanian Museum, which is possibly the type of the species'. Examination of an example, *Lt* 347, led Scott (1935: 69) to record some variations from, and some additions to, McCulloch's account; while what is in effect a concise diagnosis of the species appears in a key to the Tasmanian Clinidae (Scott, 1955: 138) that supersedes an earlier key to the Bleniidae, *sensu lato* including Clinidae (1939: 148).

Tentacles.—The rostral tentacle is the largest and most complex among local clinids. At a height subequal to its diameter the narial tube develops from the whole anterior half of its rim a conspicuous auriform lobe, as long as, or a little longer than, wide. Above the posterior half of the tube rises a large palmate flap that develops from its broad distal margin longer slender processes, tapering distally, modally 5, several or all reaching, when carried down, well on to surface of, the larger ones to or beyond lower border of, lower lip. Viewed from behind this palmate lobe usually exhibits a median groove, suggesting its possible origin from fusion of two moieties: the line of division sometimes traceable right down to base of column. Laid back, tips of longest processes reach to, or beyond, orbit; laid forward, beyond posterior nostril, a short anteroposterior slit, bordered, most noticeably internally, with a low elevation. The ocular tentacle is a flap, moderately to very broad (anterior surface slightly or pronouncedly convex, posterior more or less flat), with a distal series of 5-7 projections, which may be filiform, digitiform, or phylloid, more than one type sometimes occurring on the one structure; one or more processes may be branched. Total bulk of this tentacle is subequal to that of rostral tentacle. Laid forward, reaches to, or slightly beyond, posterior nostril; carried back, goes about halfway towards first dorsal spine. The tentacles are here illustrated (fig. 1 *e*).

PETRAÏTES FORSTERI (Castelnau), 1872

(Fig. 1 *f*)

Cristiceps forsteri Castelnau, 1872, *Proc. Zool. Acclim. Soc. Vict.*, 1: 132. Type locality: Melbourne [Victoria].

Petraïtes incertus McCulloch, 1915, *Proc. Linn. Soc. N.S.W.*, xl, 2: 275, pl. xxxvii, fig. 3. Type locality: Tamar R[iver], Tasmania.

Petraïtes incertus McCulloch. McCulloch, 1929, *Mem. Aust. Mus.*, v, iii: 350. *Id.* Scott, 1935, *Pap. Proc. Roy. Soc. Tasm.* (1934): 70.

Petraïtes forsteri (Castelnau). Scott, 1939, *Pap. Proc. Roy. Soc. Tasm.* (1938): 149.

History, size.—The basic history of the species to 1939 is traversed in the above synonymy: the entry for this form in a key in Part VII (1955: 138) is virtually a concise diagnosis of it—this key supersedes that in Part IV (1939: 148). Its attainment of a total length of about 275 makes it larger than any other local member of the family except *P. johnstoni*, which ranges up to nearly half as long again.

Tentacles.—These are here described and figured (fig. 1 *f*) for comparison with those of other Tasmanian species. Of his *Cristiceps forsteri* Castelnau observes, 'A single bifid filament over the eye'; while of his *Petraïtes incertus* McCulloch says, 'Tentacle of anterior nostril minute; orbital tentacle well developed, with a few small lobes'. The rostral tentacle presents the usual narial tube and flap, the latter subequal in length to the former, its border either entire or incised, the incisions either shallow or deep enough to result in the formation of two or three clearly defined lobes: only a hint of an anterior lip to the tube. The whole structure is small (in marked contrast to that of *P. johnstoni*), failing when adpressed to reach forward to border of preorbital, or backward to posterior nostril. The orbital tentacle, on the other hand, is decidedly longer than in that species, being carriable backwards to, or beyond, base of first dorsal spine, and forwards to, or beyond, base of rostral tentacle. It is long, slender, tapering, terminating in a small lanceolate flap, either tolerably well differentiated from the main tentacular axis, or little more than a compressed prolongation of it: one or several small leaflike lobes may develop laterally.

Genus **CRISTICEPS** Cuvier & Valenciennes, 1836

CRISTICEPS ARGYROPLEURA Kner, 1865.

(Fig. 1 *g*)

Cristiceps argyropleura Kner, 1865, Reise Novara, Fische, ii: 199, pl. vi, fig. 4. Type locality: Sydney [New South Wales].

Record.—This species, hitherto recorded (McCulloch, 1939: 350) only from New South Wales and Lord Howe Island, is here added to the Tasmanian list, a female, *Ls* 70.5, *Lt* 90.4, being included in a collection of fishes obtained in a rock-pool at Green's Beach, Devon by Mr R. H. Green (for associated species see series (*b*), subset (*iii*) under *Clinus perspicillatus*, above).

Fin counts.—D. iii, xxvii, 7. A. 11, 24. P. 12 (both fins). V. 3. C. 9.

Proportions, TLs.—Length to: first dorsal origin 82, second dorsal origin 240, dorsal termination 940, anal origin 342, anal termination 925, pectoral origin 230, ventral origin 184, vent 321. Length of: pectoral 255, longest (7th) pectoral ray 194, ventral 203. Head 255, eye 61, snout 61, interorbital 28. Depth: maximum 235, at vent 199, of caudal peduncle 41. First dorsal spines 230, 210, 99. Second dorsal: 1st, 4th, 13th, 27th spine 70, 98, 102, 114; 1st, 5th (longest), 7th ray 162, 169, 82. Anal: spines 60, 71; 1st, 4th, 13th, 21st (longest), 24th ray 84, 87, 75, 156, 87.

Remarks.—I have not at present access to Kner's original account and figure, and the following discussion takes account only of the treatment of this species by McCulloch (1908) in his review of some Australian clinids.

McCulloch's key separates *C. argyropleura* from *C. australis* Cuvier & Valenciennes, 1836 thus: in former anterior spine over front half, in latter hinder portion, of eye; in former two dorsals connected, in latter first dorsal either distinct from or jointed to base of second. Comparison of his

descriptions yields no other significant difference between the species. The difference in origin of the first dorsal constitutes a genuine, though quantitatively small, distinction. In our specimen the connexion of the first dorsal with the second is minimal, the full continuity of the membrane being traceable only with the aid of a lens.

However, in addition to differences in coloration (*C. argyropleura* being virtually immaculate, *C. australis* fairly extensively, though variably, blotched on body and fins) there are, as McCulloch's illustrations (pl. X, figs. 2, 3) show, noticeable differences both in the absolute size of the dorsal and in the relative development of the dorsal and anal. With the dorsal normally erect, in Kner's species none of the rays extend back to the level of the hypural joint, whereas in the genotype one or more overarch part of the base of the caudal. A more satisfactory criterion, however, is afforded by the relative lengths of anal rays and spines of second dorsal. In *C. argyropleura* most of the rays of the anterior half, or more, of the anal are shorter than, in the *C. australis* equal to or longer than, the dorsal spines surmounting them: specifically, the 4th anal ray is in the former species less than (about 0.8-0.9 of), in the latter species longer than (about 1.1 times) the dorsal spine (about 13th) vertically above it.

McCulloch's figures of the two species show *C. argyropleura* as having smaller mouth; rather smaller eye; longer snout; rather longer and more slender caudal peduncle; relatively longer 3rd spine of first dorsal (exceeding—in our specimen 1.4 times—1st spine of second dorsal: in *C. australis* spines equal, or the first dorsal's shorter); first dorsal base, measured from front of 1st to back of 3rd spine, rather more than once (in our specimen 1.3 times), in *C. australis* about twice, in interdorsal, measured from spine to spine; and with insertion of last dorsal ray behind, in *C. australis* opposite, insertion of last anal ray.

Tentacles.—In the present fish the ocular tentacle, which is long, simple, rounded but a little compressed anteroposteriorly, tapering, is inserted with the anterior border of its base above the middle of the pupil: when laid across the eye towards the angle of the rictus, it reaches beyond the lower margin of the pupil. The rostral tentacle is formed on the same basic plan as that found in *Clinus perspicillatus*, its essential elements being a tube terminating in the narial aperture and a fleshy extension rising above the nostril proper. However, whereas in *Clinus perspicillatus* the fleshy extension takes the form of a leaf-like lobe (distally entire or crenate) directly attached to part of the hind rim of the otherwise simple cylindrical tube, here the general appearance is rather that of a solid tentacle arising directly from the dorsum of the head and having a distally open tube fused to about the proximal one-third of its length. Shortly above the aperture the filament divides into two unequal rounded tapering elements. The whole rostral tentacle is shorter and more slender than the ocular; but when drawn forward it reaches well beyond the free border of the upper lip. Figures of the two tentacles are here offered (fig. 1 *g*).

CRISTICEPS AUSTRALIS Cuvier & Valenciennes, 1836

(Fig. 1 *h*)

Cristiceps australis Cuvier & Valenciennes, 1836, Hist. Nat. Poiss, xi: 402, pl. cccxxxvi. Type locality: Upper Derwent River [Tasmania]. (Quoy & Gaimard).

Cristiceps australis Cuvier & Valenciennes. McCulloch, 1929, *Mem. Aust. Mus.* V, iii: 350 (synonymy).

Remarks.—This is by far the most widely distributed Australian species of *Cristiceps*, being recorded (McCulloch, 1929: 450) from all Australian States except Queensland, and from Lord Howe Island and New Zealand. In Tasmania—where, up to the report in this contribution of a specimen of *C. argyropleura* from Green's Beach, Devon, it has been the only species known—it is not uncommon. *Cristiceps howitti* Castelnau, 1873, *C. macleayi* Castelnau, 1879, and *C. pallidus* Macleay are probable synonyms; *C. splendens* Castelnau, 1872 ['*Christiceps*'] is a possible synonym.

Tentacles.—The rostral tentacle usually shows some indication of the apparent proximal fusion of the cylinder and the process noted above in *C. argyropleura*, but the suggestion is less marked than in our specimen of that species. In general facies the process is long and slender: it may be simple, or divided throughout most of its length into two, or divided distally into several filaments; laid forward, extends at least to upper lip, backward about to posterior nostril. An anterior petalloid lip to the tube (its margin delicately lobate in the right tentacle of an example of *Ls* 183, *Lt* 226) is developed, but is perhaps smaller than in *Petraïtes johnstoni*. The supraocular tentacle is long and tapering; slender and rounded, or somewhat flattened and broadened, but remaining at least several times longer than wide, and terminating acutely; essentially simple, bearing at most a few quite small lobes. Carried down towards rictus, it reaches to, or just beyond, orbit; laid back, it reaches to, or beyond, base of last spine of first dorsal.

Family Ophiclinidae

The notice in Part XIII of these Observations (1965: 62) of the occurrence in Tasmania of *Ophiclinus gabrieli* Waite, 1906, previously recorded (McCulloch, 1929: 352) only from Victoria, brought the local tally to 3 species, all of the genus *Ophiclinus s. str.*—the previously listed forms being *O. gracilis* Waite, 1906, recorded for this State by Olsen (1958, 157) from George Bay, St Helens, Dorset/Cornwall, where he noted it as being a common food fish for small sharks, and the endemic *O. greeni* Scott, 1936.

A fourth species, *Ophiclinops varius* (McCulloch & Waite), 1918, is here added. The new entry is readily separable from the Tasmanian species previously keyed (1965: 61) by the characters noted in the next paragraph as differentiating groups (*a*) and (*b*).

The well-established Australian members of the Ophiclinidae [T. D. Scott (1962: 251) suggests *Neogunnellus microchirus* Herzenstein, 1896 and

N. homocanthus Herzenstein, 1896—both of which were formally included by Waite in his *Fishes of South Australia* (1923)—appear to be synonyms of *Peronedys anguillaris* Steindachner, 1854, family Peronedysidae, and *Ophiclinus antarcticus* Castelnau, 1872, respectively] fall into two clearly defined groups: (*a*) lateral line obsolete, pectoral smaller than eye, dorsal originating well behind head (*Ophiclinus varius* McCulloch & Waite, 1918, *Ophiclinus pardalis* McCulloch & Waite, 1918—the latter has been overlooked in the Check-List (McCulloch, 1929)); the 2 species differing in the vomerine teeth, these being in an angular row in the first, in a broad patch in the second: (*b*) lateral line present anteriorly, pectoral longer than eye, dorsal originating above head; this group subdividing into species with vomerine teeth forming a triangular patch (*Ophiclinus antarcticus* Castelnau, 1872, *Ophiclinus aethiops* McCulloch & Waite, 1918) and species with vomerine teeth pointed forming an angular row or series (*Ophiclinus gracilis* Waite, 1906, *Ophiclinus gabrieli* Waite, 1906, *Ophiclinus greeni* Scott, 1936). Group (*a*) is now for the first time reported from Tasmania, our 3 previously listed species constituting the second section of group (*b*).

Whitley (1941: 39) has identified *Ophiclinus gracilis* Waite, 1906 with *Sticharium dorsale* Günther, 1867, the Ophiclinidae thus becoming the Stichariidae (in the Check-List the latter family appears as the Notograptidae). *Sticharium* Günther, 1867 is certainly very closely allied to, and possibly identical with, *Ophiclinus* Castelnau (amended by Castelnau in 1873 to *Ophioclinus*): the problem is, just what weight is to be given to the several points of distinct divergence between Günther's and Castelnau's diagnoses—for some discussion of the status of Castelnau's *Ophiclinus* and his apparently synonymous *Neogunnellus* of 1875 see McCulloch & Waite (1918: 54), and for a brief comment on the possible identity of *O. gracilis* and *S. dorsale* see Scott (1965: 61). Ophiclinidae is retained by Scott (1962: 246, 249) in his recent catalogue of the fishes of South Australia.

Genus **OPHICLINOPS** Whitley, 1932

OPHICLINOPS VARIUS (McCulloch & Waite), 1918

Ophiclinus varius McCulloch & Waite, 1918, *Rec. S. Aust. Mus.* I, 1: 57, fig. 30. Type locality: Kangaroo Island [South Australia].

Generic status.—*Ophiclinops* was instituted with *Ophiclinus pardalis* as haplotype. However, the characters of that genus that are found also in *Ophiclinus varius*, but in no other form (lateral line obsolete, dorsal commencing well behind head, pectoral smaller than eye) are perhaps more significant than those not shared by the two species (vomerine teeeth in a band in *O. pardalis*, in an angled row in *O. varius*; more dorsal spines—liii; xli-xliv—and more anal rays—39; 26-28—the upper values for both fins being exceeded, it may be remarked, in other species; 'the head comparativly smaller and the body more elongate'). Of *O. varius* McCulloch & Waite observed (1918: 58), 'This species is very similar to *O. pardalis*, differing principally in having fewer dorsal and anal spines'; and the position is here adopted that these two species are perhaps best regarded as congeneric.

Record.—The distribution of this species, hitherto restricted to South Australia, is now extended to Tasmania, a specimen (probably a female), *Ls* 37.8, *Lt* 42.0, having been collected at Green's Beach, Devon by Mr R. H. Green on 27th September 1964.

It appears to be a small form, the 4 types being 42-46 long. Scott (1962: 250)—who, unaccountably, notes 'length 3½ in.'—states 'This species was described originally from preserved specimens, taken at Kangaroo Island, but has not been seen since'.

Fin counts.—D. xliii, 1. A. ii, 28. P. (both fins) 10. V. 1, 2. C. 13 main rays, total 19. The dorsal and anal counts fall within, and the 13 for the caudal agrees with, the specification of the type material; but the pectoral has 2-3 more rays. In their treatment of *O. pardalis*, described in the same paper as the present species, McCulloch & Waite give V. i, 2, remarking (p. 59) 'the spine is completely hidden in the skin': for *O. varius*, however, they record V. 2 without comment. In our example there is in each ventral a short, completely imbedded spine, the presence of which is established only with some difficulty.

Dimensions, proportions.—Some measurements, in mm, followed in parentheses by these dimensions expressed as *TLs* may be noted. Length to: dorsal origin 10.0 (265); dorsal termination, base of last ray 36.95 (978), end of membrane 38.6 (1021); anal origin 18.3 (484); anal termination, base of last ray 37.0 (979), end of membrane 38.6 (1021); ventral origin 4.05 (107); pectoral origin 6.8 (180); vent 17.6 (466). Head, with opercular flap 7.3 (193), without flap 7.0 (185); eye 1.7 (45); snout 1.05 (28); interorbital 1.05 (28). Length of pectoral 1.6 (42), longest (8th) pectoral ray 0.9 (54); ventral 3.95 (104), inner ray 3.75 (99), outer 3.2 (85); last dorsal spine 2.0 (53), dorsal ray 2.05 (54); last anal ray 1.95 (52). Depth: maximum 5.2 (138); at opercular border 4.6 (122), at vent 5.0 (132), at hypural joint 1.8 (48).

For the ratios recorded for the holotype, 45.5 long, the present magnitudes are as follows (McCulloch & Waite's values in parentheses). Head 5.2 (5.1), depth at origin of anal 7.6 (6.8), in *Ls*; eye 4.3 (4.0) in head; snout 1.6 (1.6) in eye; snout equal to ('greater than') interorbital, which is 1.6 (2.6) in eye; pectoral 1.1 (1.3) in eye; inner ventral ray 1.9 (2.0), last dorsal spine 3.7 (4.0), in head. Except in the case of interorbital relative to eye, where the discrepancy is perhaps at least in part accounted for by different conventions for measuring interorbital, the Victorian and Tasmanian entries are seen to be in quite reasonable agreement.

Remarks.—As noted in the original account, the head and abdomen are naked; elsewhere very small non-imbricating or barely imbricating scales occur. In view of Scott's statement that the species has not been seen since its establishment it appears expedient to present here some data supplementing the rather brief original account.

Anal begins under 13th dorsal spine [length to origin 2.08 in *Ls*; compare, in type, from figure,

2.15; and contrast 2.58 in *O. pardalis*, from illustration (McCulloch & Waite, 1918, pl. iv, fig. 2)—the relatively more anterior origin of the fin in the latter species being commented on by McCulloch & Waite]. Anal membrane attached to caudal, well behind caudal base (though not quite as far back as in figure of holotype), shortly in advance of attachment of dorsal membrane. Dorsal begins behind tip of pectoral by about total length of pectoral: its spines increase regularly in length caudad, the increase being most rapid in the anterior one-third of the fin; the single ray slightly exceeds the last spine. Length of first anal spine more than half length of second, the latter about two-thirds first ray: all rays simple, increasing slightly in length backwards. The pectoral, the simple and primitive-looking rodlike rays of which end some considerable distance from the margin of the fin, is bluntly pointed (less rounded than in figure of holotype): it is largely overlain by, and appears to be directly connected with, the translucent opercular lobe. Caudal rounded, nearly as broad as long.

The original account observes 'Form and structure of head and body similar to *O. pardalis*'; and the specifications (excluding those of dentition) given for the latter species (first paragraph, p. 39) are applicable also to the Tasmanian specimen.

The anterior nostril perforates a tube about twice as wide as high, lying about equidistant from orbit and anterior border of upper lip: from the hind part of the rim of the tube rises a small lanceolate flap. The outline figure of the holotype, in lateral view, shows 24 simple openings: of the 2 between the anterior nostril and the eye, that nearer the orbit is the posterior nostril. The cephalic pore system is not readily determined with certainty in our specimen; but as far as can be ascertained it follows the pattern found in *Ophiclinus gracilis*. In that species pores additional to those depicted in the figure of *Ophiclinops varius* comprise: (*a*) a transverse line of 5, of which 3, in a slightly proconcave arc, are mainly dorsal, and 2, a little caudad, are lateral; the 3 anterior pores of this set lie vertically above hindmost pore shown in the illustration: (*b*) a single median pore (rarely absent) behind median pore of (*a*) and closer to it than to base of first dorsal spine: (*c*) 1 just below base of tube of each anterior nostril: (*d*) 3 near, or with 1 or more excavating, border of preorbital, approximately level with top, middle, bottom of eye: (*e*) 1 extra mandibular pore, set very close to symphysis (in *Ophiclinus gracilis* there are of course also the pores of the lateral line, of the score or so of which 2 or 3 occur in advance of posterior border of operculum).

Coloration.—Though morphologically very similar to the type material, our specimen departs markedly from it in coloration. Thus, in the South Australian examples the ground color is light green or yellow; the main markings are 'irregular dark lines and dots on the body, most prominent along the middle of the anterior half of the body, and below the base of the dorsal fin', though they are variable and may be absent; the head is 'darker, specked with black dots': in contrast, in the Tasmanian fish the ground color is a rich dark brown (the pigment is apparently soluble in alcohol, that in which the specimen has been preserved being strongly tinted brown); the main markings are lighter than body color; the head is distinctly lighter than the body. Of the remaining entries for the type, two—'some light and dark bars radiating from the eye', 'vertical fins more or less variegated with light and dark markings'—are applicable to, though scarcely the natural specifications for, our specimen: the blackish annuli reported on the ventrals are, however, a conspicuous feature.

Rich brown ground color virtually uniform over most of trunk and tail, a trifle lighter in middle one-third, and, just in advance of vent, also in lowest one-third, of trunk; anterior portion of lowest one-third much darker: a conspicuous light, somewhat yellowish subcircular patch at base of caudal. A series of 11-14 light lichenoid markings (while the basic pattern unit appears to be subrectangular or subcircular, in some instances there are two portions of a rectangle or a circle separated by a vertical hiatus of ground color; the count in this way being indeterminate), extending, above straight line from pectoral base to last one-fourth of anal base, along whole flank from immediately behind operculum on to caudal base. Each unit consisting of from a dozen to a score of small, irregularly shaped, modally more or less rounded, whitish or pale pink spots or blotches; in most clusters a conspicuous central spot; anterior 3 or 4 marking almost contiguous, rest with interspaces ⅛-¼ their anteroposterior extent; last 3 markings extending to dorsal and anal bases. In the even dark strip below anterior ⅘ of dorsal base 3 evenly spaced light ocelli, middle ocellus just caudad of vent, anterior at about middle of trunk.

Head in general greyish or pale greyish brown, lavishly but finely punctulated and vermiculated with darker; a light, anteriorly faintly pinkish, bar (more evenly delimited and more conspicuous on left side) from eye to pectoral; 3 or 4 short dark spokes radiating back from eye; 12-14 small dark spots, anteriorly becoming short bars, along border of operculum; light patch on maxilla; tip of lower jaw dark, approaching black; inferior half of upper jaw light greyish; iris blackish with a few gold spangles; tube of anterior nostril greyish; a dark cross bar occupying posterior three-quarters of interorbital.

Dorsal dark brown, concolorous with, or a little darker than, body: pale pinkish spots and blotches, similar to those on body, 2 small, above first body annulus, 2-3 others, very small, before vent; behind vent, more or less positionally matching, in rather more than last one-third of tail continuous with, those on flank. Anterior ⅞ of anal border constituted by 6 bays (first very short) of translucent whitish, excavating, anteriorly almost to ventral body profile, the proximal dark greyish brown; latter immaculate, except for its invasion by last 3 light body pattern units. Pectoral: membrance colorless, rays dead white. Ventral whitish, more or less translucent, with, on each ray, 3-5 blackish markings, forming, according to degree of development, imperfect annuli, cross bars, or spots. Caudal mainly greyish, freaked darker, the pigment not extending quite to tips of most rays; middle rays darker.

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GLACIATION OF THE FRENCHMANS CAP NATIONAL PARK

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(With four plates and four text figures.)

ABSTRACT

Mapping of glacial landforms of the Frenchmans Cap National Park shows that an independent system of cirque and valley glaciers accumulated upon and caused considerable modification of this area during the last Pleistocene glaciation. Clearest evidence of the sequence of advance and retreat is seen in the Vera Valley where, during the maximum phase, the ice reached the Vera Creek gorge and overspilled a series of diffluence passes further upstream. The history of subsequent retreat can be traced with reference to the post-maximum moraines.

Some detailed work on the morphology of the lake basins makes possible a classification of lakes which shows clearly the nature of the glaciation and the influence of lithology. Careful consideration of the aspect, morphology, and elevation of the cirques in which many of these lakes occur provides interesting comment upon the factors governing accumulation and ablation in the maritime mountain environment of glacial and late-glacial times.

Radiocarbon assay of leaf fragments in rock-flour below peat in a bedrock depression on the lip of one of the high discrete cirques gives a minimum age of 8720 ±220 years B.P. for the final deglaciation of the Frenchmans Cap area in particular and the western Tasmanian mountains in general.

The present study is discussed with reference to some of the chronological problems of the last glaciation. The possibility of a sequence of glacials and interglacials is recognized. As the Pleistocene climate changes of the southern hemisphere form the broad context of the present study attention is drawn to analogies in the New Zealand sequence.

INTRODUCTION

The Frenchmans Cap area surrounds the prominent peak of that name in the west of Tasmania some 25 miles east of Queenstown. It is bordered to the west and north by the great bend of the Franklin River, while to the south and east lie the Lachlan and Loddon Plains. The present study, based on some 60 days field work, and on air photo interpretation, covers an area of about 70 square miles. Complete air photo coverage exists as well as maps at a scale of one mile to the inch (Frenchmans Cap National Park map and Franklin sheet), with contour intervals of 100 and 50 feet respectively.

The land varies in altitude from about 550 feet in the gorge of the Franklin to 4739 feet at the Cap summit. The peaks contained within the mountain area form a continuous range from the Clytemnaestra north to the Frenchmans Cap and the Lion's Head, then east by the razorback ridges at the head of the Livingston Valley, to Nicoles Needle and the Philps Peak massif. These mountains are formed of the resistant siliceous Precambrian metamorphics of the west and south-west of Tasmania, standing locally as ridges and peaks above the steep-sided valleys, which here are cut into softer schists and phyllites. To the east the quartzites drop away through dense temperate jungle to the Loddon Plains. These button-grass plains are base-levelled to rock-bars at the heads of gorges that eventually lead to the Franklin River, the master stream of the region. Marked by its incised character and structurally controlled sections and rapids, this river drops from 950 feet near the confluence with the Loddon to 550 feet at the confluence with the Livingston 25 miles downstream. The Cap area drains to the Franklin River in a more or less radial pattern, in places closely controlled by strike and fault directions. The area has a wet, cool, temperate climate and is largely covered with rain forest, which makes access to much of it a matter of difficulty.

No previous geomorphological work as such has been completed in the area although the physiographic problems of nearby areas to the north have been discussed by Spry (see below). Earlier publications include papers by Ward (1908a, 1908b, 1909) and papers by Finucane and Blake (1933), Blake (1936, 1937), and Ahmad, Bartlett and Green (1959). The only other references of note are the accounts of early explorers, e.g., Franklin, Philp and Rumney, and Calder.

Geology

The major contributions to the geology of the area are the papers by Spry (1957), Spry and Zimmerman (1959), Spry (1962, 1963) and Spry and Gee (1964). The first two accounts cover the geology of the nearby Mt. Mary and Mt. Mullens areas respectively, while the last three concern the Frenchmans Cap area (see map in Spry 1962, p. 112).

Spry describes the Precambrian metamorphics of the area as "strongly deformed metasediments with a low to moderate grade of regional metamorphism" (1962, p. 112). The gap area is mapped as Mary Group east of Franklin Group although Spry has recognised the presence of Scotchfire Group rocks (1963, p. 113). Further work in the area (Duncan, pers. comm.) shows the following:—

Franklin Group	Mica, garnet and albite schists with quartzites and amphibolites.	These rocks comprise the lower dissected area west of the Cap.
Mary Group	Massive and schistose quartzites. The massive quartzites are white, thickly bedded and concordant.	Comprise the main ridges and peaks of the Cap area.
Scotchfire group	Phyllites quartz-schists and dolomitic schists. The phyllites are softer than the Mary Group and have marked cleavage.	Generally underlying the ridges of Mary Group rocks and forming the saddles and gullies.

This succession is a structural one and carries no other implications. As in the adjacent Precambrian areas stratigraphic position and regional metamorphism are debatable (Spry 1962, p. 113).

Detailed mapping is often difficult due to structural complexity, strong faulting, and differential silicification which causes the rapid and irregular changes in lithology. There have been at least two periods of folding. Superimposed upon the effects of the Frenchman Orogeny is that of the later (Devonian) Tabberaberan Orogeny: it is the evidence related to the latter folding that is mapped by Spry (1962, fig. 4, p. 113).

The influence of lithology on the topography has already been outlined. The influence of structure on topography is evident in the drainage pattern. The area is in that part of Tasmania where "the folded Precambrian basement is uncovered and the rivers have evolved a trellis pattern with parallel ranges marking the strike of the harder rocks" (Davies in Gill, 1962, p. 244). This is true of the Frenchmans Cap area as a whole and of the Franklin Group rocks to the west in particular. The parts immediately surrounding the Cap itself show the influence of fault or joint control in the alignment of the valleys.

GLACIAL GEOMORPHOLOGY

It seems reasonable to suppose that the glaciers of the Frenchmans Cap area were superimposed on a fluvial landscape of dominantly joint- and fault-controlled valleys interrupted by small areas of karstic depression some of which are now occupied by glacial lakes. The resulting glacial landforms are typical of mountain glaciation in the highlands of Tasmania. Catenary troughs, cirques, cirque-lakes, comb ridge aretes and moraine ridges are common features above 2000 feet, while outwash valley trains occur at lower elevations (Fig. 1). Basically a complex and high cirques and radial valleys, the area contains eight cirque and valley glacier systems heading at altitudes between 3000 feet and 3400 feet, with lengths varying between three miles and less than half a mile, and areas from eight square miles to less than one quarter of a square mile. The following description should be read with reference to Figs. 1 and 2 and one of the published topographic maps.

The Vera glacier

Perhaps the most interesting valley is that once occupied by the Vera glacier and its tributaries. Fed from two cirques in the Philps Peak massif, the Marilyn and the Barron, this glacier left evidence of expansion to a valley glacier maximum stage and subsequent retreat to the cirques after a post-maximum still-stand.

The larger of the two cirques heads at a col known as the Barron Pass, a gap opened by headwall sapping in the comb ridge extending from the Nicoles Needle group eastwards to Philps Peak. The erratic blocks on the crest of the pass are much more likely to be protalus than moraine left by transfluence across the pass. The exact limits of inundation of the ridges is hard to assess from air photos because the overridden appearance of the high schist outcrops is due mainly to the geological structure. The hanging Marilyn valley has been selectively eroded out of dolomite. Below the 1000 foot backwall topped by Mary Group quartzites and quartz-schist, Lake Marilyn, which is 60 feet deep, is contained behind a rock lip of dolomite. Down valley a second and much smaller lake, now rapidly being filled by colonizing vegetation, hangs above a 400 feet drop to Lake Vera. Here, at the meeting point of the Marilyn and Barron glaciers, the half-mile long lake is 180 feet deep and very much "down at heel" (see Fig. 3).

The nature of the preglacial valley into which the glacier expanded has caused an interesting series of features. Like the Tahune valley to the west, the upper section is joint controlled. Both the Tahune and Vera valleys turn sharply to follow the strike direction in their middle sections. Unlike the Tahune glacier, the Vera glacier was severely restricted where its valley changed direction, so that the low strike ridges on the outside of the bend were overridden as the ice spilled out through five diffluence passes overlooking the Loddon Plains. Although there is no evidence of how far these outlet glaciers advanced towards the plains, they were responsible for the agglomeration of tillflow (Hartshorn 1958-footnote p. 477, Sharp 1960, p. 333) and poorly stratified outwash, the coarse nature of which is explained by the comparatively high gradient. Below these deposits, valley trains were laid down on the plains as may be seen where Philps Creek has incised five feet into outwash immediately upon reaching the flatter gradients of the Loddon Plains. The aerial photographs suggest that this valley train was braided.

The weathered state of the schist boulders in the till on the flanks of the hills separating the diffluence ice tongues above the upper Vera Plains indicates that the deposits are among the oldest surficial sediments in the region.

The lower Vera valley itself provided a further outlet. It was considerably modified, the preglacial gorge-like walls being overridden and a giant roche moutonnee formed at the valley bend, the walls of which exhibit vertical stoss and lee features (Lewis 1949). Ice from two north bank tributary cirques heading at the comb ridge west of Nicoles Needle may have joined the lower Vera glacier at this stage.

The maximum extent of the lower Vera glacier coincided with the Vera Creek gorge. Drift fills

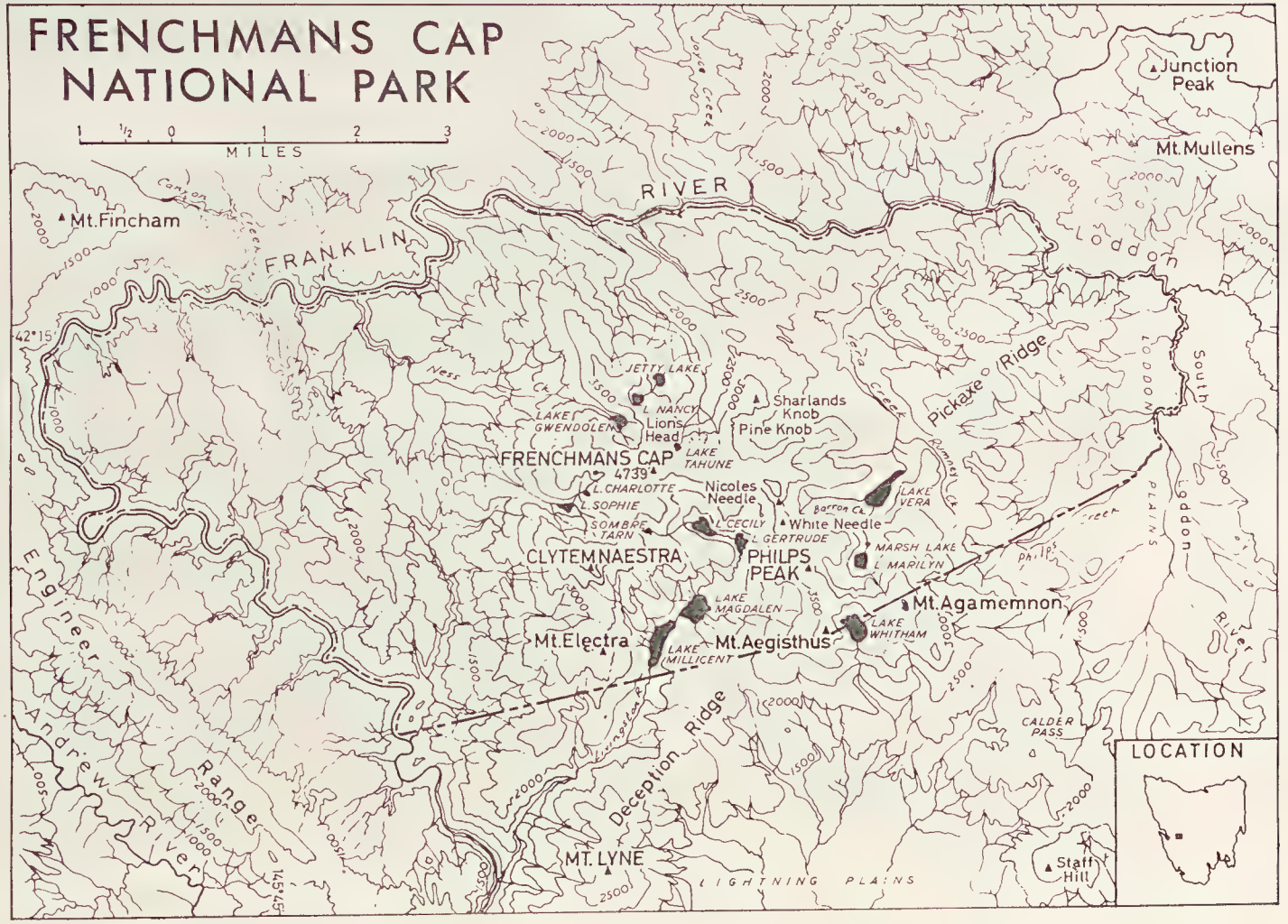


FIG. 1.—Location Map. Frenchmans Cap National Park (Nomenclature from the National Park Map and from the climbing notes of J. Middleton-Elliott).

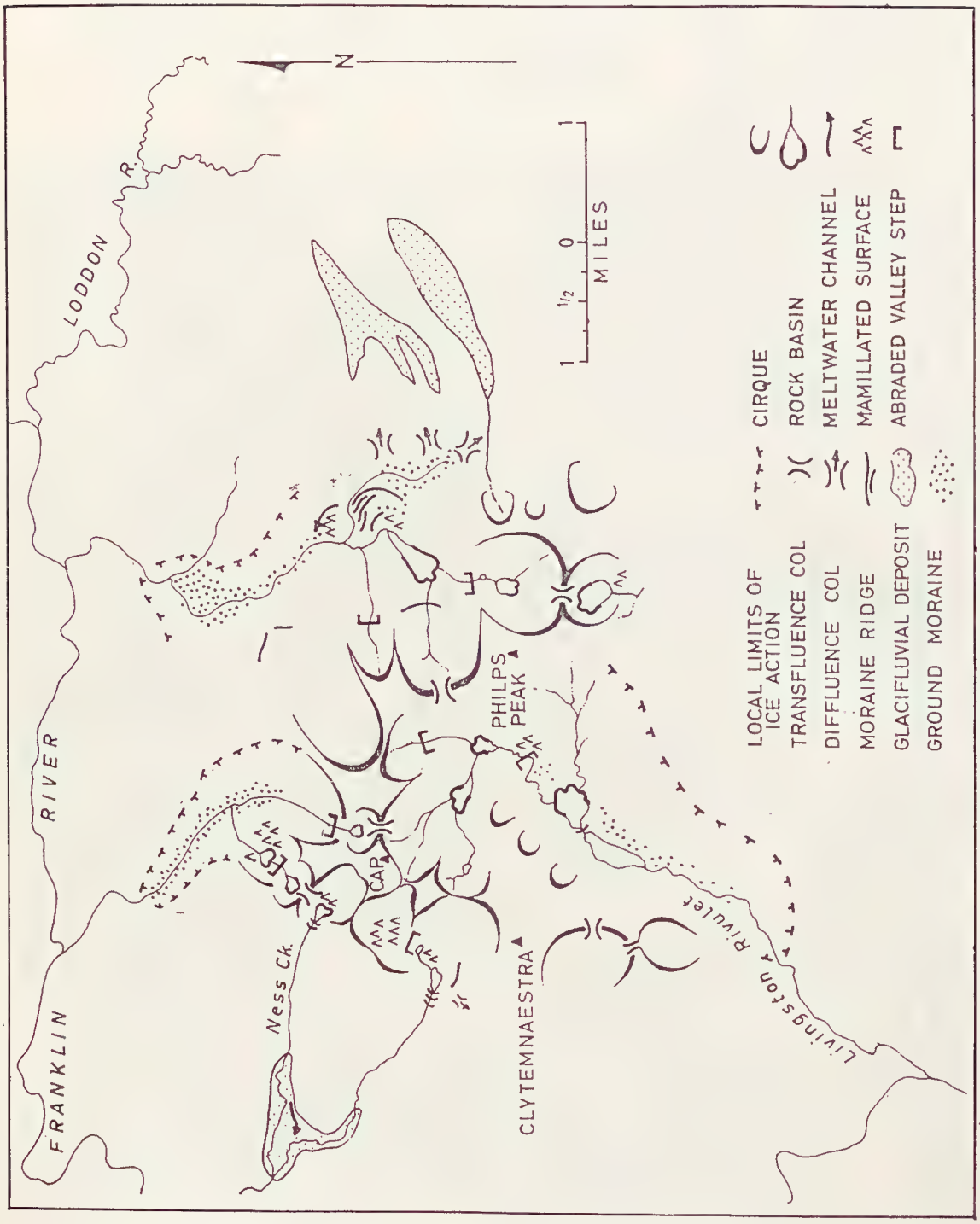


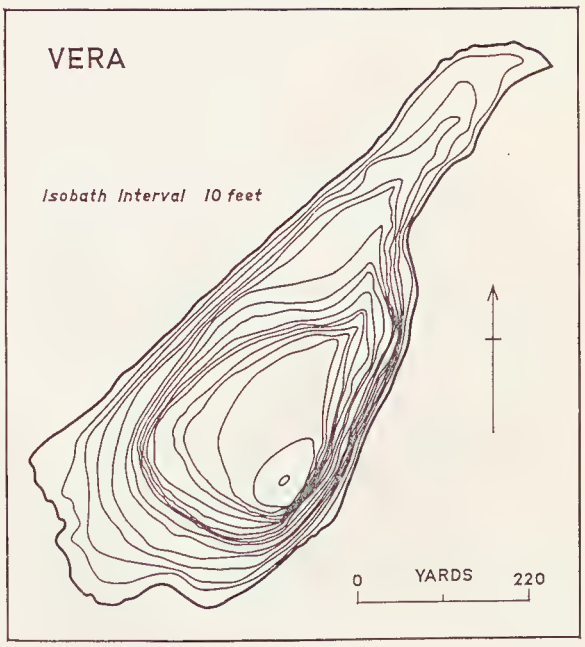
Fig. 2.—Glacial Landforms of the Frenchmans Cap massif.

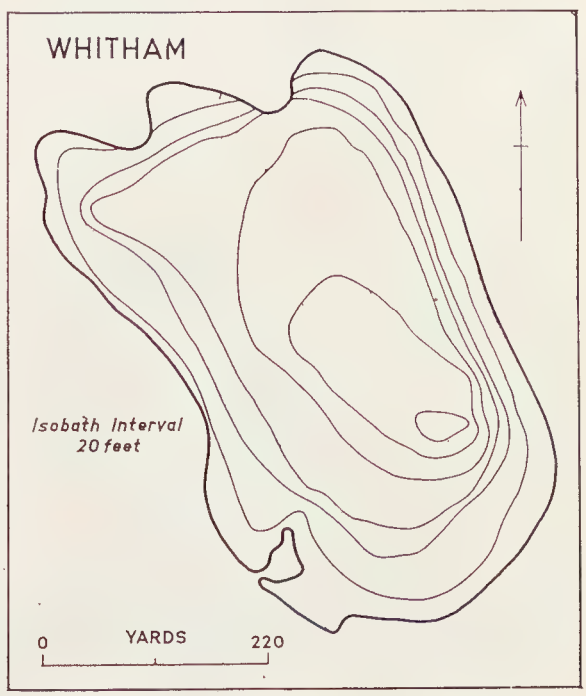
the lower half of the valley above the gorge and has been terraced by postglacial river erosion, the present Vera Creek being incised into the till. In places the till extends to some 50 feet above the river level and must be at least 30 feet thick. It contains a large percentage of boulders, is coarse, and permeable, with a matrix of pronounced sandiness. The glacier snout may have extended a short distance into the gorge, but, as would be expected, there is no evidence for this. The narrow (20 feet to 30 feet at the base) 200-300 feet high gorge marks a distinct change of character in the valley. Above the gorge are glacial deposits; below, the valley is deeply incised and V-shaped. The same is true of the Tahune valley to the west. That glaciers from the Frenchmans Cap area were responsible for Pleistocene damming of the Franklin valley as suggested by Spry and Zimmermann (1959), to explain the presence of varved clays in the Artists Hill-Mt. Mullens area upstream is not immediately apparent.

At the glacial maximum ice in the upper Franklin and adjacent valleys may well have been coterminous with the ice of the St. Clair district and *ipso facto* with that of the central plateau area. Ice tongues from such a huge accumulation area would be pushed long distances. Ice in the Cap area on the other hand accumulated in a strictly limited area, from which the ice soon moved to the lower levels of the ablation zone. It is suggested then that although evidence is lacking it is most likely that the same ice which deposited till on Artists Hill and left large erratics at about the same height near the foot track below, and north of, the Mt. Mullens saddle, might well have placed a moraine dam downstream. The maximum extent reached by outer lobes of the main central ice cap of Tasmania is still a matter of debate. That glacial advance into the Franklin-Collingwood river junction area was a maximum stage feature is illustrated by the weathered state of the Artists Hill till (Spry and Zimmermann 1959, p. 3). It is important to realise that the location of this till is a better indication of its age than is the weathering state of dolerite boulders contained therein. The amount of weathering of dolerite till stones in a given time will vary from place to place due to differences in composition of the dolerite, composition of the till matrix and relation to ground water fluctuation. Moreover there is the possibility that drift containing weathered dolerite was transported en-masse, probably in the frozen state. This process has been suggested as a possible explanation for the presence of fragile lumps of Permo-Triassic sandstones in the bedded moraines at Lake St. Clair (Derbyshire 1965, p. 381). Perhaps these factors explain the anomalies of the weathering state of different tills of probable similar age, e.g., the Arm River till and the Artists Hill till (Spry 1958, Spry and Zimmermann loc. cit.).

The next marked stage in the history of the Vera glacier is indicated by the large recessional moraine at Lake Vera. This rises steeply 350 feet above the lake outlet and 200 feet above the Upper Vera Plains. A cover of ground moraine and scattered erratic boulders was left between the lake and the diffluence passes from which the glacier retreated. The Lake Vera moraine is aligned north-south while the glacier responsible for its

FIG. 3.—Isobathic maps Lake Vera and Lake Whitham.





formation came from the southwest. This alignment was probably governed by the rate of retreat of the various parts of the ice front from the diffluence passes (for some of the ice tongues had spread out more acutely to the main direction of flow than others), and also by the position of strike ridges which outcrop at several places on the northern end of the moraine. The retreat of the glacier at this stage can be traced in detail.

The differential withdrawal from the maximum extent at the diffluence passes was most rapid from the southernmost tongue. This left the eastern end of the moraine area open for meltwater escape over the ground moraine of the upper Vera Plain. This water escaped northward around the snout of the ice and thence down the lower Vera valley. At first this was accomplished along the now dry meltwater channel on the east side of the giant roche moutonnee. Subsequent retreat exposed lower escape routes until drainage very similar to that of the present was established.

This apparent stage of equilibrium of the Vera glacier, marked by the main moraine, was terminated by a slight advance which produced a fine push moraine capping the crest of the main feature. There followed a retreat in three main stages as shown by three small moraine ridges plastered aslant the northern end of the proximal slope of the Vera moraine (Plate 1). These ridges, clearly demarcated by their narrow tops and steep slopes, are emphasised by the meltwater channels between them. The orientation of these ridges reflects the position of the retreating ice tongue against the Vera moraine and also the bedrock strike. The alignment of the strike ridges of dolomite and quartz-schist which outcrop at this place suggest that the Vera moraine, although the largest in the whole region, is bedrock-cored. That these ridges should affect the alignment of the smaller moraines indicates that the ice was much thinned in comparison with the earlier time when drift was deposited regardless of outcrop orientation. The travertine deposit on one of the recessional moraines suggests the presence of dolomite bedrock close to the surface of the western end of the moraine ridges. Further retreat resulted in the exposure and channelling of the lower Vera Plain and in the building of the small moraines at the outlet of Lake Vera. At this stage the ice had thinned to such an extent that the truncated spur on the east side of the glacier diverted the snout so that the moraine here was built mainly on the western side. Meltwater escaped around its eastern end and became the forerunner of the present lake outlet. Several large dolomite erratics occur on the lake shore and on the slopes of the moraines. These, and the dolomite till-stone exposed in a section prepared for the collection of samples for particle-size analysis, had their origin in the dolomite of the Marilyn cirque.

The history of the glacier concluded with its retreat to the Marilyn and Barron cirques. A moraine in the Barron cirque may signify still-stand there, but no definite evidence was found of a similar stage in the Marilyn cirque. In general the high cirques of the Frenchmans Cap area lack moraines on their lips. Such accumulations as occur there are in most cases best ascribed to protalus formation.

This general lack of cirque lip moraines is interesting. On the one hand it suggests that the rock basins contained active ice mainly during the glacial maximum (see Dort 1957). The lack of evidence for re-occupation of overridden cirques after the retreat of the Central Plateau ice cap (Jennings and Ahmad 1957) may be taken as support for this. Certainly rotational slip of cirque glacier ice, postulated as the cirque forming agent elsewhere (Lewis 1960), is, following the calculations of Lewis (1949), much more likely in the Frenchmans cirques at a time of maximum ice thickness.

On the other hand active ice may have occupied the cirques until late glacial times without leaving a moraine, because of a lack of excavated material in a post-maximum stage.

The Livingston glacier

The bulk of this glacier accumulated in the deep cirque in the lee of the Cap that is now occupied by Lake Cecily. Bounded by the Clytemnaestra Ridge to the west and the Deception Ridge to the east, the glacier was constricted at its maximum at the lower end of Lake Millicent. The ice may well have overtopped the eastern trough shoulder while its western neve fields under the Clytemnaestra Ridge were carving out a series of cols, the main one of which is the South Col of the Cap.

Lake Cecily is at the base of the deepest cirque in the region—its backwall being topped by the 1500 feet face of the Cap itself. The glacial origin of the cliff is indicated by a number of things, although it is possible that the scarp is related to a fault. The great depth of the Cecily cirque is typical of lee-side accumulation areas in Tasmania and this is generally recognised as a function of aspect. The lack of buttressing common to cliffs resulting from periglacial solifluction suggests that the Cap face was immediately associated with the Cecily glacier. Although it is unlikely that active ice covered the top of the Cap it is probable that a thin carapace of neve contributed meltwater which aided headward sapping as would the moderately dense jointing of the quartzite. This glacier, together with the Tahune, Gwendolen and upper Cwm glaciers, was in the process of reducing the Cap to a hornpeak when climatic amelioration cut short the process.

The extent of the Livingston Valley glacier is problematical. Air photo interpretation suggests that glacial deposits extend into the Livingston gorge below Lake Millicent and that, as mentioned above, ice may have overtopped Deception Ridge. It is unlikely that glacial deposits would be preserved in the gorge of either the Livingston or Franklin Rivers. As for the Lightning Plains immediately southeast of Deception Ridge, Wells (1955), writing of the geology of the general area southeast of the Cap, states " no evidence of glacial physiography was found in the area and Pleistocene glacial deposits are lacking ".

Many of the apparent anomalies in the Livingston Valley can be understood if the shape of the valley cross section is considered. It is over one and one half miles from crest to crest across the valley at Lake Magdalen whereas below Lake Millicent this distance is less than one half mile. Considering the size of the accumulation area for

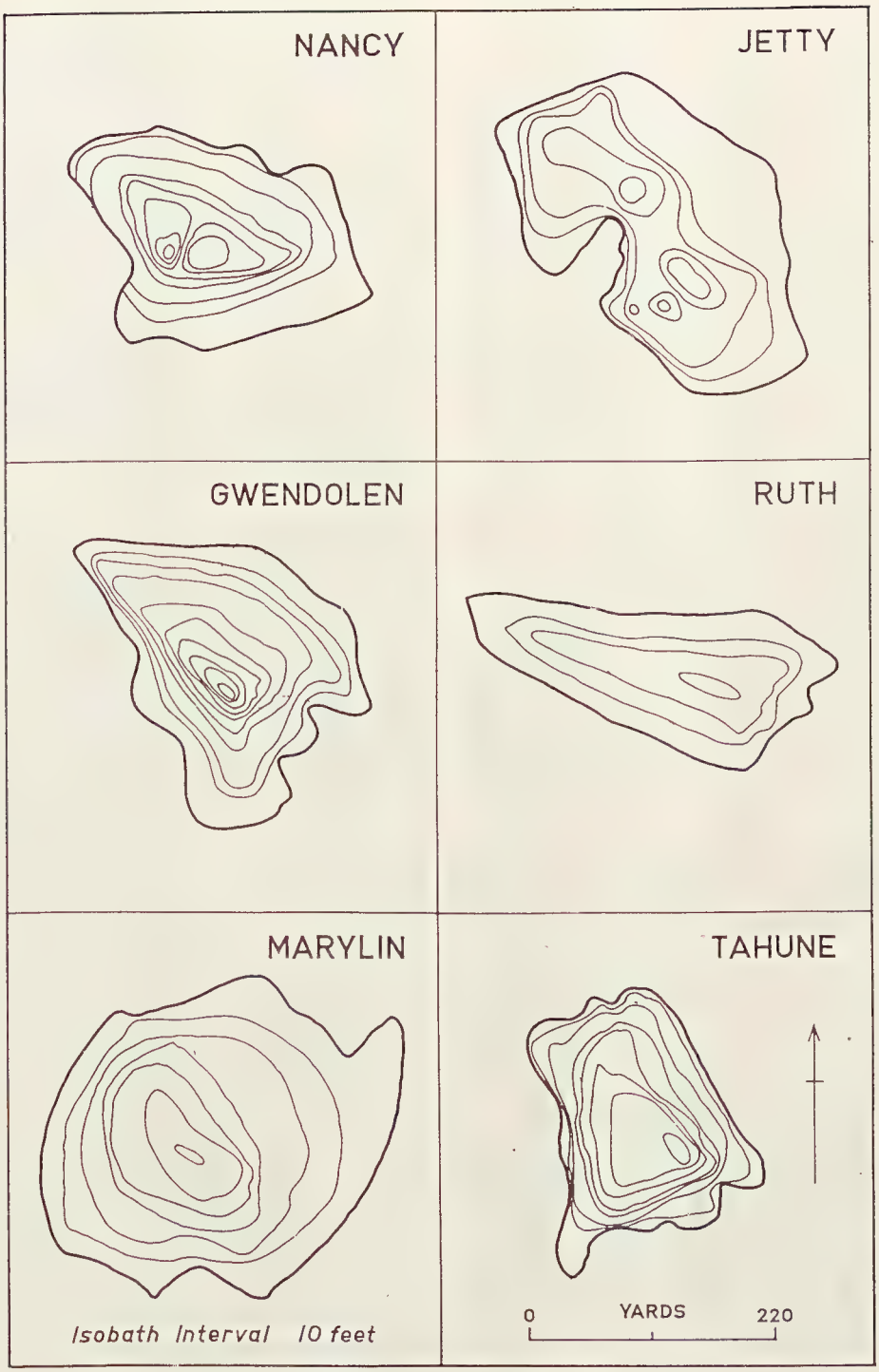


FIG. 4.—Isobathic Maps of the smaller cirque lakes.

this glacier it is justifiable to postulate penetration of the lower valley with only limited maximum stage transfluence of Deception Ridge.

A more detailed history of the valley would require lake sounding. The main lakes were too large for accurate single-handed work with sounding line and the depth sounder used was incapable of receiving signals from the muddy lake bottoms. The following comments are therefore tentative. Lake Millicent lies immediately upstream of the valley constriction and is probably partly moraine dammed. Lake Magdalen also is moraine dammed. However its situation in the widest part of the valley below a mammilated valley step which forms the low cliffed northern shoreline of the lake suggests it is a partial rock basin. Lake Gertrude, situated below a small cirque below the junction of softer Scotchfire and the Mary Group rocks has swampy shores on deep clay and silt detritus. The lake has been subject to infilling from both the Cecily and Gertrude cirques. The small cirques on the west wall of the trough probably represent the late cirque stage seen in the other valleys.

The Sophie and Upper Cwm glaciers

The trough of the Sophie glacier is located on the west side of the Clytemnaestra Ridge. This glacier was substantially augmented by ice from the Upper Cwm situated under the Cap summit on the west-southwest side. This ice may have been coterminous with the ice of the Gwendolen glacier (via the west col) and the Cecily glacier (via the south col), at the glacial maximum. It descended to join the Sophie glacier over two steps, between which lies the small rock-basin tarn, Lake Charlotte. Some of the finest mammilated rock surfaces to be found in Tasmania occur in the Upper Cwm. Smooth stoss and lee profiles in the roches moutonnees reflect north-south movement although inherent weaknesses in the quartz-schist bedrock have been exploited regardless of ice movement direction as seen by the small, comparatively deep, rock basins (see Plate 2).

Lake Sophie is a shallow lake (30 feet deep at most), dammed by a relatively extensive deposit of drift in the form of a series of recessional moraines. A section ten feet deep, exposed by the lake outlet, shows a bouldery till of quartzite, quartz-schist, and chlorite schist boulders and cobbles in a sandy matrix. The lateral moraine standing some 200 feet above the southern edge of the lake and running parallel to it is particularly well formed. Westward (downstream) it curves more and more sharply towards the lake, but is not coterminous with the recessional moraines.

Further south between the Clytemnaestra and Mt. Electra a large west-facing cirque parallels the Sophie valley. It is a comparatively poorly developed form which, nevertheless, probably overtopped the ridge to the southeast to become coterminous with the southernmost cirque overlooking the Livingston Valley. Considering the position of these cirques it is not unlikely that snow patches developed on the Deception Range in the lee of Mt. Lyne (3050') several miles to the S.S.W.

The Gwendolen glacier

Parallel to the Sophie glacier, and to the north, the Gwendolen glacier occupied the trough overlooked by the west and north cols of the Cap. A lake basin, 90 feet deep, was eroded in massive quartzite and quartz-schist under the deepest part of the glacier, which, judging by the height of the Nancy col on the northern side of the trough, was over 400 feet thick at its maximum stage. At this time both the Sophie and Gwendolen glaciers were cascading down V-shaped valleys below their troughs, and melting rapidly among the outwash deposits, till and protalus deposited during the glacial advance to this maximum. These deposits are braided below the Gwendolen trough and several larger abandoned channels can be seen below the Sophie trough. Glacial deposits have buried low ridges of the softer Franklin Group rocks between the Gwendolen and Ness Creeks.

Subsequently the drift deposits at the end of the Gwendolen trough were laid down. This material is predominantly composed of gravel and boulders with sandy fines. Under the backwall (which is not as uniformly vertical as it might have been had the geological structure been favourable) lee ends of well formed roches moutonnees project into the lake.

The Tahune glacier

On the north side of the Cap the Tahune glacier headed beneath a steep backwall rising from 2200 to 4700 feet. This was broken at the 2700 foot level by the small, high cirque containing the rock basin of Tahune. The main valley, as mentioned above, is probably joint or fault controlled in its upper section, and strike controlled in its lower section above the Tahune gorge. At the maximum extent slight diffluence occurred from the outer part of the valley bend, while the glacial snout reached at least one and a quarter miles to the Tahune gorge. As with the Vera valley there is a distinct change of character of the river valley at the gorge. There is also a contrast between the upper and lower sections of the glaciated part of the valley. The broad catenary shape of the upper section shows that it was more susceptible to modification than the strike valley section, despite the additional contributions of ice from the Nancy and Jetty Lake areas to this part of the valley. These cirques were bounded to the east by the upper Tahune ice while they built small lateral moraines on their western sides. Air photo interpretation suggests strongly that the position of these cirques was governed by what is taken to be a well marked structural weakness there. The drop of 650 feet between the two cirques would have accommodated a cascading glacier. Lake depths, rock lips, and the mammilated bedrock of the platform surrounding Jetty Lake indicate similar abrasive action to that already described in the Upper Cwm. In neither of these places were any striations found. Other less spectacularly abraded areas likewise lacked such marks of ice movement direction. The conclusion is reached that these metamorphic rocks are characterised by so many structural foliations that it is impossible to separate lineations due to glaciation from those resulting from the surface expression of minor structural features. The Tahune cirque hangs nearly 1000 feet above the Tahune trough headwall. It is a small steep-sided and overdeepened cirque excavated in Scotchfire dolomite under the north face of the Cap. Lake Tahune, although little more than 100 yards

across is over 70 feet deep and is contained behind a dolomite rock lip through which it drains by way of solution channels. The rock-lip has a thin cap of bouldery till and protalus.

The Whitham glacier

Lake Whitham lies at 3060 feet in an overdeepened cirque southeast of Philps Peak. Outcropping dolomite at several places around the lake shore indicates selective erosion of Scotchfire dolomite as in the Lake Marilyn cirque. The maximum extent of the Whitham glacier is unknown for the ice cascaded steeply after passing over the glacially moulded quartz-schist rock-lip. This lip is well smoothed to a height of at least 70 feet above the lake level (Plate 3).

The East Philp glaciers

The only other glaciers of the area were the small "precipitation shadow" cirques high on the eastern slopes of Philps Peak massif overlooking the Loddon Plains. One of these cascaded on to the southernmost diffluence tongue of the Vera glacier. The other was situated on the east side of Mt. Agamemnon. Neither were overdeepened enough to contain lakes and much of the material deposited in them is not till but protalus, including protalus ramparts. As with two other cirque-like features nearby they would have held only snow-patches for most of the last glacial period.

GLACIAL DEPOSITS

Thirteen till samples were analysed by sieving, decantation and hydrometer analysis in the C.S.I.R.O. Soil Laboratory in Hobart. The samples brought out for analysis vary in size from 40 lbs. to 2-3 lbs., the boulders having been measured in the field. The small clay content of most samples is explained by the fact that most of the bedrock from which the tills were derived comprises resistant quartzites and quartz-schists, and that most very fine particles are carried away by meltwater in areas of mountain glaciation. Tests for lime content of samples showed that any calcareous materials had been leached out, a condition expected in this area. The results in fact were typical of analysis of tills derived from conspicuously jointed rocks which usually show a high proportion of boulders and pebbles in a matrix of pronounced sandiness.

The differing proportions of quartzite and quartz-schist in tills makes differentiation based in weathering difficult as quartzites remain almost completely undecomposed as boulders in surficial deposits. As a result, the predominantly quartzite till of the lower Vera valley shows very little sign of weathering, while the Vera diffluence pass tills, which may reasonably be assumed to be of similar age, contain weathered schist cobbles and boulders. In contrast to quartzite, dolomite boulders may become completely decomposed as till stones, as found in pits excavated in the Vera retreat moraines.

In considering the significance of weathered till particles the question arises as to how much drift is derived from the preglacial weathered mantle and how much is derived from the mechanical action of ice on bedrock. While the ability of ice to abrade and erode unweathered bedrock is clearly evident in the powerful glacial moulding of stoss and lee features, there is little evidence on which to base an assessment of the amount of material contributed to the drift by pre-glacial weathering. The weathered dolomite boulders mentioned above almost certainly decayed after emplacement in the till as glacial transport in mountain valleys would be unlikely to allow the retention of cohesion in weathered boulders. The preglacial weathering of the till stones in question is rendered further unlikely by their presence in post-maximum stage tills.

GLACIAL LAKES

A classification of lakes (Table 1) of the Frenchmans Cap area is useful in illustrating the glaciation of the area. It should be used in conjunction with a topographic map and all figures.

TABLE I

Type	Name	Remarks
A. Cirque lakes due mainly to glacial erosion and overdeepening.	Whitham, Marilyn, Tahune	Definite roxen lakes all selectively eroded in Scotchfire Group rocks with a high or 100% dolomite content.
	Nancy, Jetty*	Other rock basins eroded in quartz-schists and quartzites
	Gwendolen	a valley head cirque with a low partial moraine dam.
	Cecily	partially moraine dammed—deeply eroded in softer Scotchfire Group rocks
	Sombre Tarn	small cirque lake on valley side now almost filled by sedimentation and protalus.
B. Valley lakes of compound origin due to erosion and deposition.	Vera	glacial overdeepening in Scotchfire rocks at the junction of two glaciers.
	Sophie	valley "cirque" lake—shallowed by debris from higher tributary cirque with greater accumulation area.
	Gertrude, Magdalen, Millicent	valley lakes possibly marking retreat stage of Livingston glacier. Lake Millicent may be a miniature glint lake (see below).
Other	Marsh Lake, Lake Charlotte	Small rock basins on steps below cirques.

* Jetty Lake is eroded in Scotchfire quartz-schist and might be classed as a roxen lake.

Lake Millicent is thought to fit Hutchinson's type 29 (1957, p. 160), in that it is probably a rock-basin resulting from "glacial corrasion in specific sites where the ice flow is impeded by the pre-existing topography", although the examples quoted (op. cit. pp. 68 and 160), are on a much larger scale than the one in question here. Attention is drawn to the different use of the term "glint lake" by Charlesworth (1957, pp. 250, 265, 285). The term "roxen lakes" (Charlesworth 1957, p. 265), has been employed here for lakes selectively eroded in the dolomite lenses of the Scotchfire Group rocks. It is possible that some other rock basins were initiated in depressions in dolomite which no longer outcrops.

The isobathic maps (Figs. 3 and 4) were plotted from soundings made with the aid of a rubber boat and sounding line. Plotting was done from bearings taken from the boat and from shore. They show that in some cases considerable overdeepening has occurred, especially in the high rock basins, most of which have their deepest points nearer the backwall than the lip, which is of course typical of cirque lakes in general.

ASPECT AND MORPHOLOGY

Although the glaciation of the area was imposed on a small, somewhat isolated massif, with a generally radial drainage pattern, the effects of advantages possessed by south and east facing valleys and cirques for the accumulation of glacial ice can be seen. These advantages are two in number. First, in areas of prevailing westerly winds, south and east facing valleys are likely to accumulate more snow due to both orographic precipitation and snow drifting. However, this advantage is also possessed by north facing valleys in the lee of north-south ridges. Secondly, south and east facing slopes are more protected from insolation (see also Charlesworth 1957, p. 298). It is significant that the largest glaciers accumulated in the lee of north-south ridges while the largest cirque faced south-east on the lee of the Cap itself.

Closely related to this effect is the asymmetry of form shown mainly by the north-south ridges, in particular the Clytemnaestra Ridge including the Cap (Plate 4). As previously observed by A. N. Lewis (1929) this profile of steep lee slopes is typical of most of the glaciated areas of Tasmania. In the Frenchmans Cap area the effect is emphasised in places such as the Clytemnaestra Ridge where the resistant quartzite and quartz-schist has been worn away on the lee sides to expose softer underlying rocks while the quartzite remains to cap the ridge and form the western slopes. Post-glacial processes have tended to preserve and in some cases emphasise this general asymmetry on the crests of the north-south ridges, the very tops of which take on a striking resemblance to the crests of mobile sand dunes due to the erosion caused by the growth of heavy snow cornices along the crests on the lee sides. Referring to the action of such snow cornices created by wind on ridge crests, Charlesworth (1957, p. 299), states that they "tore off astonishing amounts of rock when they broke away". The prevailing westerlies over Tasmania caused not only the necessary drifting, but also the eventual deflation of fines exposed by melting or washed from under snow. Snow cornices form on the Clytemnaestra Ridge during the present winters and have been known to last regularly into October. They might reasonably be assumed to have been semi-permanent in late glacial and early post-glacial times.

MULTIPLE GLACIATION

The cirques can be divided into two groups on the basis of altitude. Half those mapped in Fig. 2 fall between 2100 feet and 2300 feet and the other half between 2700 feet and 3400 feet. Early work in Tasmania used cirque levels to differentiate between the separate glaciations (Lewis 1922, 1924, 1933). It is now recognised (for example, Jennings and Banks 1958) that there is no reason why cirques at different altitudes cannot contain ice at the same time, and, if they do not, then it is the high cirques that contain ice as a result of retreat of ice from all lower levels. Glacial features in these late stage cirques will therefore be younger than features down valley.

Cirque levels have also been used to determine orographic snowlines within different stages of the one glaciation. However, given the altitude necessary for the existence of solid precipitation the exact siting and level of any cirque is pre-determined by factors of accumulation (aspect, precipitation amount and slope angle) and lithology. Obviously to assume different ages for cirques on the basis of their altitudes is only an introductory exercise to more detailed study. The "roxen lake" cirques and the small high East Philp cirques of the Frenchmans Cap area illustrate the effect of local conditions on cirque glaciation.

Nor do the glacial deposits, which are in general a more promising indicator, provide any evidence of multiple glaciation. Higher tills are in some cases obviously less weathered than tills in lower areas. This indicates nothing other than the usual single phase sequence of cirque glaciers expanding to a maximum as valley glaciers, followed by retreat into the original cirques. No signifcant differentiation of the fluvioglacial sediments is evident. Although the evidence is consistent with with only one glaciation it is well to remember that proof of multiple glaciation in Tasmania may yet be forthcoming (Patterson 1965, Derbyshire et al. 1965, p. 3). The present investigation is essentially a reconnaissance one and, in an area such as this, evidence of multiple glaciation is not quickly available, it being generally recognised as more difficult to obtain in areas of alpine glaciation than in areas formerly covered by continental ice-caps. Ice streams are more likely to erode evidence of previous glaciations because they are confined to the one route of movement. Even where evidence exists, it is hard to distinguish unless by obvious differentiation of weathering because of a general lack of differentiation in texture, lithology and colour of deposits of different ages, arising from this confined flow and the fact that the same rocks are eroded each time. Weathering in mountain areas produces immature and incomplete soil profiles. Further, comparative weathering in mountain areas of high rainfall cannot be used as effectively as in areas of continental glaciation, because glacial materials are generally non-calcareous either in their original state, or because of high leaching rates. In the valleys of the Cap area it is unlikely

that glaciers of penultimate and earlier glaciations extended beyond the well marked limits of the last at the Vera, Livingston and Tahune gorges. All drift belonging to these glaciers would then have been redistributed such that if it existed at all it would now be very difficult to distinguish.

Two possibilities remain: either previous glaciations were much slighter than the last or insufficient snow accumulated to form a significant quantity of glacial ice. Gentilli (1961, pp. 478-479) argued on climatological grounds for the existence of glaciations prior to the last while admitting the lack of relics from it. Probably older glaciations were no more extensive than the last, with periglacial processes predominating for much of the time. In this case the resulting landforms would have been destroyed in the interglacial periods by fluvial erosion. This would mean that the latest glaciers formed and advanced upon a fluvial landscape.

Therefore, bearing the difficulties in mind, the conclusion is reached that the Frenchmans Cap area shows evidence of only one glaciation. Present opinion (Jennings and Banks 1958) correlates this glaciation with the Wurm or Wisconsin glacial phases of the northern hemisphere. The suggestion is made that previous glaciations may well have occurred despite the lack of evidence.

Certainly the evidence in the area correlates readily with the most recent glacial phase. Preservation of moraines and other glacial landforms, the generally undeveloped state of drift weathering, the presence of illite in some deposits (Charlesworth 1957, p. 226), the depth and newness of the lakes despite active infilling, all strongly suggest this. The equally fresh evidence of glaciation in the nearby Linda Valley (where radio-carbon dating of fossil wood found in varves puts the initial advance there at approximately 26500 years B.P. (Gill 1956)) is ascribed to the latest glacial phase, the radio-carbon date corresponding with the beginning of the Wisconsin glaciation in North America.

Problems of the last glaciation

The systematic significance of the present study lies in relating it to (i) the general glacial history of Tasmania and (ii) factors affecting ice accumulation in alpine areas in order that the climate changes responsible may be correctly interpreted. To this end some major problems of more than immediate significance are discussed. These are the extent of the last glaciation, the sequence of events in that glaciation, and the dating of these events.

(*a*) *Extent*

The maximum extent of the last glaciation in Tasmania is at present undefined. Beyond the well worked glacial features of the individual glaciated areas lies a zone of uncertainty: cf. Jennings and Banks (1958), map p. 299 and Derbyshire et al. (1965). In mountainous regions like the Cap area, where valleys often descend into gorges, evidence in this outer zone is both scanty and problematical. On the central plateau the limits of the last ice sheet remain unmapped. Indeed some workers point to the possibility that features of the eastern plateau may be referable to an earlier glaciation (Jennings and Ahmad 1957). To the west the great gorges of the Fury, Mackintosh and Canning Rivers belie glaciation but the tills exposed on the Murchison Highway are unlikely to have been deposited by ice of local origin. To the north the picture is as yet far from clear despite its importance to current engineering projects in that area. To the south and east similar problems leave current thought in a state of flux. (Derbyshire 1963, p. 108; Jennings and Ahmad 1957, p. 74).

The uncertainty in defining the maximum extent of the Cap valley glaciers has been mentioned in previous sections. Accordingly Fig. 2 should not be regarded as final. In the light of these difficulties, future consideration of the maximum glacial advance here and in the rest of Tasmania should take account of the following possibilities:—

(1) If the last glaciation attained an early, comparatively brief and extensive maximum, the evidence for this might be obscured by the subsequent periglacial processes.

(2) A distinction must be drawn between the mountain glaciers and the Central Plateau ice cap, which at one time had a potential accumulation area of some 600 square miles or more. In contrast, the area above the firn line in the Frenchmans Cap area cannot, at any time, have been greater than six square miles.

(*b*) *Post-maximum stage sequence of events*

The various retreat stages of the valley glaciers have been dealt with above. The glaciation of the Cap area almost certainly involved a synchronous valley glacier maximum stage that must have grown from, and must have retreated to, the high cirques. It was not possible to date the valley retreat stage. Perhaps future work in this or other parts of Tasmania will provide details of the fluctuations of the last glaciation. If the New Zealand evidence can be taken as an indicator of Southern Hemisphere climate changes in general, a sequence of three glacial advances might be expected with the last retreat beginning some 14000 years B.P. after the Kumara 3 and Poulter advance of the Otira glaciation of South Island (see Suggate 1965, p. 84).

Present work so far in the Frenchmans Cap area has yielded only one datable deposit. A radiocarbon assay of wood and leaf fragments taken from rock flour (mainly (unweathered) quartz and mica particles according to X-ray analysis—McIntyre pers. comm.) and sediment beneath 1½ metres of peat in a small bedrock basin on the lip of the Nancy cirque at 3400 feet gave a date of 8720 ±220 years (before 1950) (Kigoshi 1965 pers. comm.). This date, which can be regarded as a minimum age for the deglaciation of the high cirques of the Frenchmans Cap area in particular and the western Tasmanian mountains in general, is the closest to a true date for deglaciation of the western high cirques presently available. Among the vegetal fragments dated were branchlets of *Microcachrys tetragona* which today grows mainly in the higher more exposed parts of the Cap area.

CIRQUES, SNOWLINES, AND THE GLACIAL-AGE CLIMATES

Among the methods used for quantifying Quaternary climate change is that taking cirque levels as indicators of glacial age snowlines and temperatures. Davies (in Gill 1962, p. 245) and Galloway (1965, Fig. 2) have spoken briefly, and in general terms, of the Tasmanian snowline while at the same time mentioning the problems involved in defining it. The difficulties are due to the east-west climatic contrast across Tasmania and the complications inherent in assessing the inter-relationships of temperature and precipitation changes (Galloway op. cit., p. 609).

It may be assumed that snowline levels change with progressive deterioration and amelioration of climate during glacial times. It is important when suggesting former snowline elevations and the corollary climatic inferences to define the stage of glaciation to which it refers. Maximum stage snowlines might be deduced from climatic data derived using Ahlmann's curve (1948): evidence of former lower limits of solifluction and tree lines being used to help establish temperature while modern climatic records of temperature and precipitation (ablation season length, &c.) may also be used.

Cirque stage glaciation snowline levels on the other hand are orographic snowlines, and, as mentioned above, this is strictly a function of climate and lithology (page 126). Wind and precipitation shadow effects can be seen in both individual mountain ranges and across the whole Island. Cirque glaciation, except as part of an advancing hemicycle, is essentially a late-glacial or "post-glacial" event. Late-glacial cirque ice is very sensitive to climatic factors, and, at least as investigations to date are able to ascertain, existed mainly in the high discrete cirques which are forming the subject of further investigation.

SUMMARY OF GLACIATION

The following sequence of events for the last glaciation is suggested. Climatic deterioration resulted in the accumulation of snow and the formation of snow patches in the depressions of a fluvial landscape, probably between 30000 and 26000 years B.P. The early accumulation hollows were provided by larger solution features in dolomite areas and by structural weaknesses elsewhere. Cirque glaciers formed, ice continued to accumulate, and valley glaciers advanced to a maximum. All this time the highest peaks and ridges stood above the glacial ice as indicated by the evidence of prolonged frost shattering.

In the Vera valley, glacial ice accumulating in the Marilyn and Barron cirques advanced down valley and over the low dolomite and quartz-schist ridges where the Vera Plains now stand, and discharged over five diffluence passes at the east end of the plains and also down the lower Vera valley to the Vera gorge, before which it was joined by the Pickaxe and Davern glaciers flowing down short, steep gradients from heads on the north side of the Nicoles Needle Ridge.

At the maximum stage the Livingston glacier reached the gorge above the Franklin River junction possibly over-spilling the low section of the east trough wall (Deception Ridge). Small cirques formed above the west side of the glacier in the lee of the west trough wall (Clytemnaestra Ridge). The Tahune glacier had reached its maximum extent at the Tahune Creek gorge and may have discharged a small ice tongue over the diffluence pass beneath Sharlands Knob. Meanwhile, the Gwendolen and Sophie glaciers were cascading down on to the Ness Creek Plains. The Whitham glacier had overflowed its cirque and the east Philp cirques contained active ice at this stage. The valley constrictions and diffluence passes and the hanging valley snouts that characterised the glaciers at this stage were unfavourable for the building of well marked terminal moraines, and much of the debris was carried away by the constricted and fast-flowing meltwaters. These were responsible for the valley trains of the Loddon Plains and Ness Creek Flats.

The post-maximum stands are better marked in some valleys than in others. In the Vera valley the glacier thinned at the point of greatest constriction, so that retreat took place rapidly to this point. Ice retreated from the diffluence passes and a major stillstand was recorded in the main Vera moraine. After a slight advance that emplaced a push moraine on top of the main moraine, retreat with six halts took place until all that remained of the glacier was in the Barron and Marilyn cirques. The former cirque contains a moraine testifying to this halt in the retreat.

The retreat stages of the Livingston glacier are less obvious but it seems reasonable to postulate a retreat from the maximum extent to the lower end of Lake Gertrude with a major halt across the deposits separating Lakes Millicent and Magdalen. The retreat of the Tahune glacier is not marked by any one moraine ridge although there is ample drift on the floor of the valley. The final stages saw the ice retreating into the Tahune, Jetty and Nancy cirques. The moraine at the mouth of the Tahune cirque contains a large proportion of protalus from the north face of the Cap. The lack of moraine in the high cirque is as much due to abrasion having reached below the zone of open weathered joints as to a postulated brief late-glacial cirque phase.

The Sophie and Gwendolen glaciers retreated into their flat hanging troughs from their steeper lower valleys. The former, being smaller and therefore more sensitive than the other, built a series of low moraines near the trough mouth while the Gwendolen glacier left a more uniform, though also ridged, till cover. The Sophie glacier retreated into the upper Cwm from which limited outwash was derived for the deposit of a small delta in Lake Sophie immediately below Lake Charlotte.

The Marilyn cirque glacier left a shallow protalus cover on the lip. The Whitham glacier retreated to its cirque and melted without leaving a moraine. The absence of debris is explained by the lower headwall.

After the glacial maximum the East Philp cirques contained only stagnant ice or neve and behaved generally as nivation cirques or snow patch hollows. Protalus ramparts formed in the northern of these cirques as well as in the neighbouring nivation hollows.

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Plate I.—Aerial view of the Vera Retreat moraines. Diffluence pass middle-left, main Vera moraine with push moraine crest lower centre, recessional moraines on proximal moraine edge. Hanging cirque containing Lake Marilyn upper right. Lake Vera middle right.

Plate II.—Aerial view from west of Clytemnaestra looking north-northwest, across the Sophie cirque valley into the Upper Cwm. Cap summit upper right.

Plate III.—Abraded rock lip of Lake Whitham cirque. Looking southwest.

Plate IV.—Asymmetrical ridge and lee side excavation. View from the summit of Clytemnaestra looking north to the Cap summit. Note quartzites overlying darker coloured dolomites, schists, and phyllites of the Scotchfire Group.

[Plate II.—Geography Department, University of Tasmania. All other photos by the author.]

CHARLOTTE CLEVELAND 1819-1884—AN EARLY TASMANIAN ARTIST

By

C. Craig

(With six plates.)

Before the introduction of photography most educated people were taught to sketch. A great deal of our knowledge of early colonial cities, villages and buildings in general is due to the habit such people had of sketching what interested them. Tasmania was very fortunate in this respect. The purpose of this paper is to record what is known of Charlotte Cleveland, an amateur artist who left behind a few sketches of considerable historical interest. The information in this account has come firstly from Mr. A. H. Weedon, Charlotte Cleveland's grandson, and secondly from an article "The History of the Cleveland or Ainslie Estate" contained in a pamphlet on Cosgrove Park Home published by the Launceston General Hospital when Cosgrove Park was opened.

Charlotte Cleveland (née Barry) was born in London on 20th July 1819. She was the daughter of James Barry and was the niece of Sir Charles Barry (1795-1860) R.A., F.R.S., the architect of the Houses of Parliament in London and of many other public buildings. She was also the cousin of Alfred Barry (born 1826) Bishop of Sydney and Primate of Australia (1884-1889), Canon of Windsor (1891), Assistant Bishop of West London (1897), &c., and the author of many theological works; a cousin of Edward Middleton Barry (1830-1880) architect and assistant to his father Sir Charles Barry; and a cousin also of Sir John Wolfe Barry, K.C.B., (1836) an eminent engineer who designed, amongst other structures the Tower Bridge, Kew Bridge and the Barry Docks in London.

Nothing of importance is known of her until 1844 when she married William Charles Cleveland. Before his marriage William Cleveland, accompanied by his brother James, had sailed to Van Diemen's Land in the 1830's in their own schooner, the 'Mumford", and had for some time traded between Launceston and Sydney in that vessel. Whilst in Van Diemen's Land, William Cleveland bought land in several parts of the northern portion of the island, including a property in that part of Launceston then known as the "Sandhills". He named the property "Normanstone" and it included all the land from Peel Street, South Launceston to Machen's brickworks in the south and to the western side of the Dark Hollow beyond Westbury Road. During this time James died and was buried in the cemetery in Cyprus Street, Launceston. After James died, William returned to England and married Charlotte Barry in 1844.

After their marriage William and Charlotte Cleveland lived in England and on the Continent for eight years. During this period it is presumed that Charlotte Cleveland pursued her art whilst travelling in Europe, as a drawing by her of a view in Venice is in the possession of Mr. A. H. Weedon. During this period four children were born to William and Charlotte. One of them, a daughter named Rose, who was later to become Rose Weedon, was born in Brussels (Belgium) on 19th April 1850.

On 9th April 1852 William and Charlotte and their four children left England for Tasmania in the "Mermaid" and arrived in Launceston on 4th August 1852. They obtained lodgings in a boarding house in York Street (Mrs. McKenzie, proprietor) and later rented a house in Eardley Street, South Launceston. Both these houses are still in existence (1965). William then had a house constructed on his property at "Normanstone" on the Sandhills (1858). The bricks for this house were made by hand on the property by the original Machen who was in William's employ and who later started the brickworks in South Launceston which are still in existence.

William and Charlotte lived at "Normanstone" until 1864, during which time four more children were born. During their residence at "Normanstone" William and Charlotte were largely instrumental in the building of St. Paul's Church in Cleveland Street. A very fine window was presented to the Church by their children in their memory and it is still in the Church. In 1864 they left Launceston to live in Melbourne. Normanstone was then let to the late Henry Edgell, a well-known insurance manager in Launceston, and he and his family lived there for many years. The property was then sub-divided and most was sold. The house and grounds were bought by a Mr. Ainslie who later sold it to the Tasmanian Government. "Normanstone" house was demolished and, what is now called Cosgrove Park was built.

Charlotte Cleveland left Melbourne for a trip to England in February 1871 but in March of that year the ship—"Queen of the Thames" — was wrecked near Durban. Having lost all her possessions in the wreck she, and other survivors, were taken overland in bullock waggons to Cape Town. She finally reached England in May 1871 and returned to Melbourne in 1872.

Owing to the ill-health of William Cleveland the family returned to Launceston about 1877 and lived at "The Hollies" in High Street which was later demolished to make way for the Queen Victoria Hospital, and here William died in 1879.

He was buried in the Cyprus Street Cemetery. After William's death Charlotte moved to the Victoria Parade, Windmill Hill, where she died in 1884. She also was buried in the Cyprus Street Cemetery. A cross erected on the family plot in the Cyprus Street Cemetery bore the names and dates of Charlotte's family but it is not known what has happened to the cross since the cemetery has been turned into a playing field.

The Weedon whom Rose Cleveland married in 1879 was Mr. Hardwicke Weedon a member of an old Tasmanian family. He was a member of the Board of Management of the Launceston General Hospital for fifty-one years and was its Chairman for four. Mr. A. H. Weedon is Mr. Hardwicke Weedon's son.

CHARLOTTE CLEVELAND'S TASMANIAN PICTURES

1. *"A View of Christs College, Tasmania"*

Beneath is written "The Western Tier forming the background of the picture is eight miles distant. In winter the ridges are covered with snow. Large lakes are on the summit."

The building is shown and is thus described "The Warden's Lodgings are to the left with a low gable and verandah. The tall building next contains the Chapel, Hall and Museum and the building standing back is occupied by the Dormitories and the senior and junior boys' day rooms. The Masters lodgings are in a building hidden by the trees but forming the right side of the Quadrangle. The new iron schoolroom, stands at the back. The little summerhouse to the left belongs to the boys and is in their cricket ground."

Pencil sketch, signed and dated 1856. 17.8 x 25.3 cms.

The view shown is much the same as that of the Butler Stoney's *A Residence In Tasmania*: Smith Elder & Co., London, 1856, page 106 and the above description is best read whilst looking at that engraving. Christ College was intended to be a colonial Harrow. It was opened in 1846 but owing to financial and other difficulties it closed in 1857. The buildings were demolished.

2. *"Creek of the North Esk. The bathing place of the boys of Christs College Bishopsbourne with a distant view of part of the Western Tier, Tasmania".*

The words "A creek of the" have been crossed out and in another hand the words "The Liffey running into the" have been substituted [It should be South Esk].

Pencil sketch, signed and dated 1856. 17.8 x 25.3 cms.

3. *"The Signalling Station & Cottage, Windmill Hill. View of the Cottage at the Flag Staff Station Launceston Tasmania".*

Coloured pencil sketch, signed and dated 1854. 13.5 x 19.3 cms.

This is only known picture of this signalling station. It shows both methods of signalling. There is the flagpole from which were hung various coloured flags which indicated to the citizens of Launceston the type of vessel approaching up the river. There is also the semaphore. There were two semaphore signalling systems in Tasmania. One passed messages between Port Arthur and Hobart by means of five stations. The other conveyed messages between Low Head and Launceston and stations were built on Mount George near George Town, Mount Direction sixteen miles north of Launceston, and on Windmill Hill. The latter system was first used about 1835 and it was closed about 1869.

4. *"Windermere Tamar, Tasmania"*

Coloured pencil sketch, signed and dated 1856. 22.7 x 30.5 cms.

This shows the Church and Dr. Gaunt's house. Dr. Matthias Gaunt arrived in Van Diemen's Land in 1831. He was granted 2,560 acres on the east Tamar which he named Windermere. With help from others he built the church (1843) which still stands. He also built a house north of the church, and, south of it, on the river bank, a mill. The print of these buildings on page 59 of Bishop Nixon's *The Cruise of the Beacon* London 1857 was taken with the artist looking south. Charlotte Cleveland's view was taken looking north. Only the church and house are shown. The house is partially obscured but it appears to have been built of weatherboard. Only the church now stands.

5. *"Windermere Church on the Tamar, Tasmania"*

Coloured pencil sketch, signed and dated 1854. 24 x 35.5 cms.

This shows the church and some buildings on the other side of the river.

6. *"Ben Lomond from Bostock Hill near Clynevale"*

Pencil sketch, signed and dated April 1856 25.5 x 17.4 cms.

The above sketches are in the possession of Dr. C. Craig, Launceston.

7. *Hobart Town*

There is no caption.

Pencil sketch signed and dated January, 1854. 21.9 x 32 cms.

This drawing is very similar to the lithograph by John Skinner Prout entitled "Hobart Town From The New Town Road".

The above drawing is in possession of Mr. Stewart Ferguson, South Springfield.

8. *Launceston*

Pencil sketch. 20.6 x 29.5 cms.

This pencil drawing is included as, although it is signed "Chas. Eddy", the Weedon family have always believed that it was drawn by Charlotte Cleveland.

"Partial View of Launceston from the River. 1. Invermay. Mr. W. Henty lives in this hamlet. 2. Valley of the North Esk leading to Patterson's [*sic*] Plains. In it is The English Cemetery. 3. Flagstaff Station and Windmill Hill. Partial view of Launceston from the River. 4. St. John's Church. 5. St. Andrew's Scotch Church. 6. Wharf. 7. Our Valley and the commencement of the Sand Hills (Norman Stone) as I have called them. 8. White Hills." Signed "Chas Eddy, 1854".

References

The details given above are derived from two sources—

1. William Cleveland's diary which is now in the Mitchell Library, Sydney.
2. Charlotte Cleveland's Journal which is in the possession of her grandson Mr. A. H. Weedon of Tatana, near Launceston.

Plate I.—*A View of Christs College, Tasmania.*

Beneath is written "The Western Tier forming the background of the picture is eight miles distant. In winter the ridges are covered with snow. Large lakes are on the summit.". A detailed description of the building then follows. See text.

Plate II.—*Creek of the North Esk.*

The bathing place of the boys of Christs College, Bishopsbourne, with a distant view of part of the Western Tier, Tasmania.

Plate III.—*The Signalling Station and Cottage, Windmill Hill.*
View of the Cottage at the Flagstaff Station, Launceston, Tasmania.

Plate IV.—*Windermere, Tamar, Tasmania.*

Plate V.—*Windermere Church on the Tamar, Tasmania.*
Dr. Gaunt's house is to the right.

Plate VI.—*Ben Lomond from Bostock Hill, near Clynevale.*

CONSIDERATIONS ON THE EMPLACEMENT OF THE JURASSIC DOLERITES OF TASMANIA

By

F. L. Sutherland

(Queen Victoria Museum, Launceston, Tasmania)

(With 4 text figures.)

ABSTRACT

The emplacement of the Jurassic dolerites of Tasmania is considered in terms of the tectonic structure of Tasmania at the time of intrusion. At this time Tasmania consisted of a Permo-Triassic sedimentary cover draped in gentle downwarps over an uneven basement of folded Precambrian-Palaeozoic rocks, with uplifted highs in the west, northeast, and east.

Characteristics required for the recognition of dolerite feeders in Tasmania, particularly cones, are discussed and the structures are examined in the light of these. In form, the cones are generally asymmetrical structures. In many cases there is insufficient evidence present to determine whether they represent rootless conical sheets emplaced under a flotational mechanism, or whether they represent conical feeders. Possible modes of emplacement are considered. Some of the cones appear to be secondary structures developed in the sedimentary cover at about the base of the Triassic sequence, possibly from cupola-like structures on underlying sill sheets.

The intruding dolerite was controlled by, and also caused, extensive Jurassic faulting. The recognisable tectonic pattern is shown. The faulting in places suggests the development of horst-like and graben-like structures in the downwarps between the main pre-existing highs. Some of the major Tertiary faults of the State were originally lines of Jurassic movements, and there is a suggestion that the Tertiary Midlands, Cressy, Tamar, and possibly the Derwent and Oyster Bay trough structures were inherited, in part, from Jurassic structures. It is considered east-north-easterly and north-easterly tensional forces were important in producing the fault pattern and that it was controlled to a certain extent by the margins of the main pre-existing highs and structural trends in the basement. The greatest fracturing took place in the central trough of the main downwarp between the highs of western and eastern Tasmania. Dolerite magma probably rose here from feeder dykes and its emplacement was controlled by compensation surfaces, giving rise to transgressive sills, meeting in numerous large dykes, with considerable rafting of sedimentary blocks. Away from the main downwarp, sill sheets were more extensively developed and in the broad scheme their emplacement apparently followed compensation paths. Cone structures were emplaced, apparently mostly on the margins of the downwarps and on small intervening highs. On the upper flanks of the main highs, feeders were mainly plug and dyke-like plugs. Where basement highs exceeded heights of about 4,000 feet above the basement level in the downwarps, dolerite feeders were lacking.

At the time of the dolerite intrusions Tasmania was probably situated below the Antarctic Circle, just east of the Ross Sea, and comparisons are made with the similar Ferrar dolerites of Antarctica. Differences in the emplacement of the dolerite appear to be due to structural differences between the two regions at the time of emplacement. Only limited comparisons can be made between Jurassic trends associated with the dolerites of the two regions, but maxima in the trends of Tasmanian dykes were apparently similarly orientated to those of Antarctica.

INTRODUCTION

Tasmania is extensively intruded by tholeiitic dolerite (for map see Spry 1962) in the form of dykes, sills, plugs and cones (Carey 1958a; Spry 1962). The intrusion is Middle Jurassic (167 million years; McDougall 1961). The pattern of intrusion is complex, the dolerite spreading out through sub-horizontal Permo-Triassic strata from feeders rising through the folded Precambrian-Palaeozoic basement. Secondary feeders rise from the dolerite spreading out from the primary feeders. The intrusion was associated with extensive normal faulting. Little is known concerning the factors controlling the sites of intrusion and the emplacement of the dolerite, and no overall tectonic pattern has yet been recognised. This paper represents a preliminary attempt in this direction.

RECOGNITION OF PRIMARY FEEDERS

Primary feeders such as dykes, plugs, and possibly cones can be recognised where the Permo-Triassic cover has been stripped by erosion, exposing the folded basement. Elsewhere other methods are necessary to demonstrate downward extension of dolerite structures into the basement. Thus McNeil (1965) has suggested that the dolerite capping of St. Patrick's Head represents a plug rather than a sill remnant, on the grounds of the differentiation of the dolerite. Conversely, McDougall and Stott (1961) show from gravity measurements that the dyke at Red Hill is unlikely to continue in depth to the basement.

Carey (1958a) demonstrated a technique for locating possible feeders by means of isostrats. Dyke-like feeders are indicated by parallel closely spaced, successively falling isostrats; plugs and cones by concentric isostrats falling successively inwards. Isostrat patterns similar to those of cones, however, can result from alternative structures. Further, even if a conical structure is demonstrated it may not represent a feeder, but merely a basin-shaped sheet emplaced under the flotational mechanism outlined by Bradley (1965). Characteristics required for the recognition of cone-like feeders in Tasmania are set out below.

1. The dolerite is demonstrably *in situ*. Dolerite ranges in Tasmania are commonly skirted by talus deposits resulting from Cainozoic glacial, periglacial, and gravitational action and these, in cases, have been mapped as dolerite outcrops (see McNeil, 1965; Sutherland, 1965; Jennings, 1963, pp. 91-92).

2. The dolerite body is annular in plan with inwardly dipping sides and rises from a basal feeder channel. Annular outcrop may be obscured by the rugged dissection of the Tasmanian landscape and later Tertiary faulting; while the inward dip of the sides may be obscured by lack of exposure, or only become apparent by compensating for Tertiary epeirogenic tilting. In many cases the root zone will not be exposed and the presence of a feeder channel, or otherwise, cannot be confirmed by direct observation.

3. Isostrats and structure contours are concentric in plan and fall successively inwards towards the centre of the cone. Isostrats, unlike structure contours, are not greatly affected by the factors mentioned under 2. This is discussed in detail by Carey (1958a).

4. The roof rocks within the cone are uplifted dilationally with respect to the outside rocks.

5. The conical structure may be expressed physiographically as a basin where exhumed by erosion of the softer sedimentary core.

6. The intrusion of the cone may be accompanied by concomitant radial, peripheral and tangential faulting, particularly in the uplifted roof rocks. Strong updragging and shattering due to forcible intrusion of the cone may also occur.

7. Rocks within and around the apex of the cone may show greater baking effects than is normal with sedimentary-dolerite intrusive contacts. This is due to the concentrated heating here. Pyrite in the original sediments may be converted to pyrrhotite (Carey 1958a).

8. Differentiation zones of the dolerite will parallel the flare of the cone, passing from the upper zone along the inward margin, through the "pegmatitic" and central zones, to the lower zone along the outer margin. This has been demonstrated by Spry (1958), and Sutherland (1964). There will be a corresponding variation in density (Jaeger and Green, 1958). Granophyre may also occur within the upper margin of the cone (Anand Alwar, 1960; McDougall, 1964).

9. Gravity and magnetic surveys over the structure should show profiles compatible with a cone structure rising from a basal feeder channel.

CONE STRUCTURES IN TASMANIA

(Figures 1 and 2)

Several cone-like structures have been mapped in Tasmania to date and two further possible cases are proposed here. These structures are examined in the light of the characteristics listed above.

1. Great Lake Structure (Carey, 1958a; Jones, 1963; Haigh, 1963; McDougall, 1964). This structure shows characteristics 1, 2 (in part), 3, 5, 8 and 9. Only small patches of roof rocks remain. If these belong to the Permian System as suggested by McDougall (1964) then they also demonstrate characteristic 4. McKellar (1957) in the Weston Creek area notes a tendency towards an arrangement of faults radial from Great Lake. The faults are possibly Jurassic in origin (characteristic 6). There is thus considerable evidence for a conical structure at Great Lake. The large thickness of the dolerite here (Jones, 1963) suggests it is a centre of intrusion but this has not yet been proved conclusively.

2. Huon Structure (Carey, 1958a): This structure shows characteristic 1, 2 (in part), 3, 4, 5, 6 and 7. Further detailed mapping and geophysical surveying is being carried out here by the Geology Department, University of Tasmania. These investigations tend to confirm the presence of a cone-like feeder (D. E. Leaman and I Naqvi, pers. comm.).

3. Esperance structure (Carey 1958a): A small conical feeder was proposed here on the basis of characteristics 3 and 5. Further investigations are required to establish this.

4. Billop Structure (Carey 1958a): The proposal of a small intrusive cone at this locality is based on characteristics 2 and 3. Further detailed investigation is again required.

5. Golden Valley Structure (Carey, 1958a; Sutherland, 1965): Carey suggested the presence of a small conical feeder here on the basis of characteristics 2, 3 and 6. Further investigation by Sutherland indicated the need for more detailed examination of the structure in regard to characteristic 1.

6. Zeehan Structure (Spry, 1958; Blissett, 1962; Bradley, 1965): This shows characteristics 1, 2 (in part), 4 and 8. Characteristic 3 is not demonstrable as the Permo-Triassic cover has been mostly removed by erosion, but is in agreement with the stratigraphic level of the intrusion of the dolerite to the south-west at Firewood Siding. Spry notes that the Permian Tillite outcropping around the cone is more indurated than is normal but whether this indicates characteristic 7 is not certain. There is, as yet, insufficient evidence to determine whether the structure represents a conical feeder (Carey, 1958a), or a rootless conical sill sheet (Bradley, 1965).

7. Bloomfield Structure (Anand Alwar, 1960): This structure was mapped as a small cone sheet and shows characteristics 1, 2, 3, 5, 6 and 8. Characteristic 4 is not readily apparent as the rocks within and outside the cone consist of lithologically similar rocks of the Triassic System.

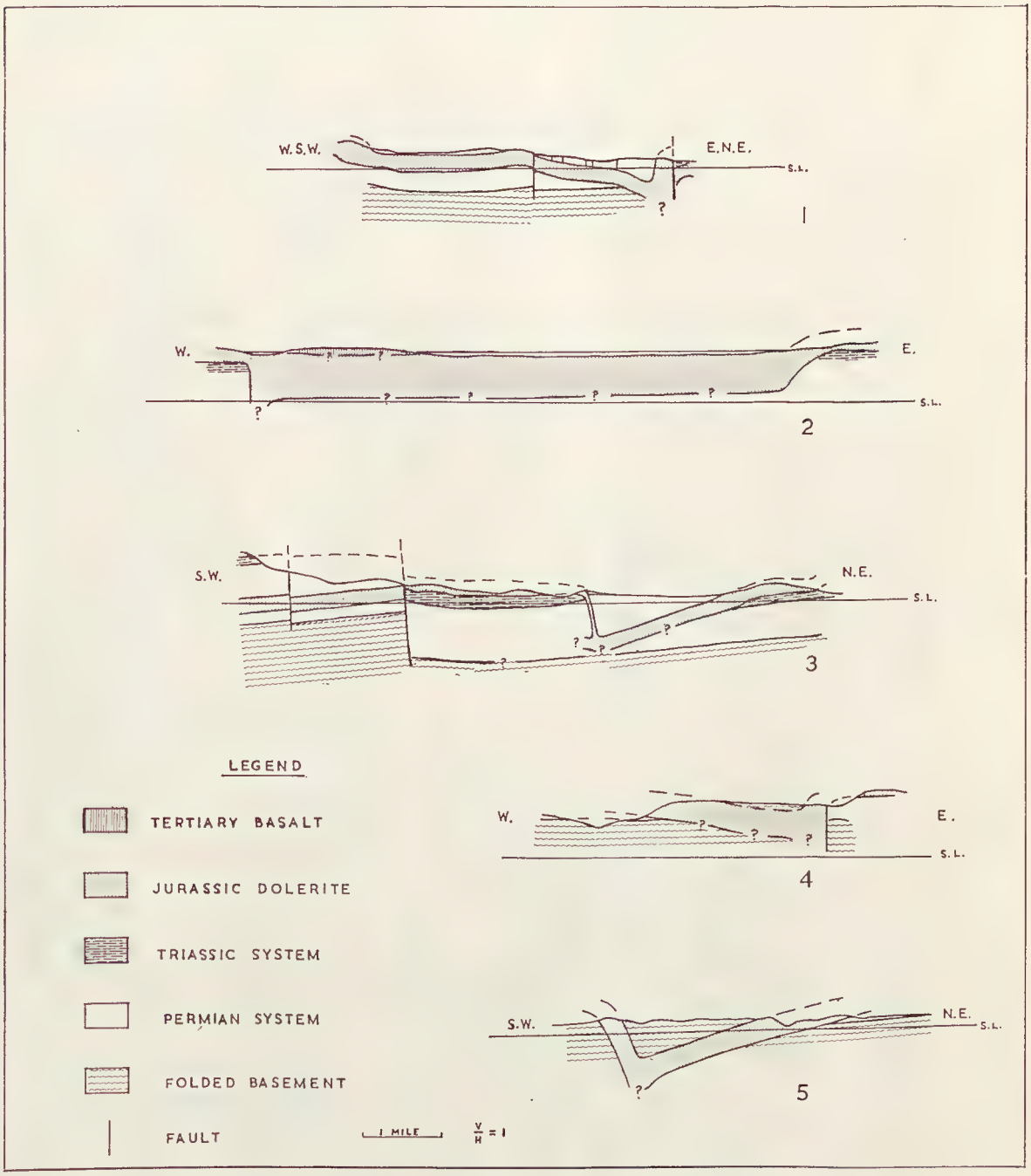

FIG. 1.—Sections through some Tasmanian cone-like structures. *1.* Collinsvale Structure (from the mapping of Sutherland 1964); *2.* Great Lake Structure (after Jones 1963); *3.* Mangalore Structure (from the mapping of McDougall 1959); *4.* Cheyne River Structure (from the mapping of Gulline, Longman, and Matthews 1963); *5.* Zeehan Structure (after Spry 1958).

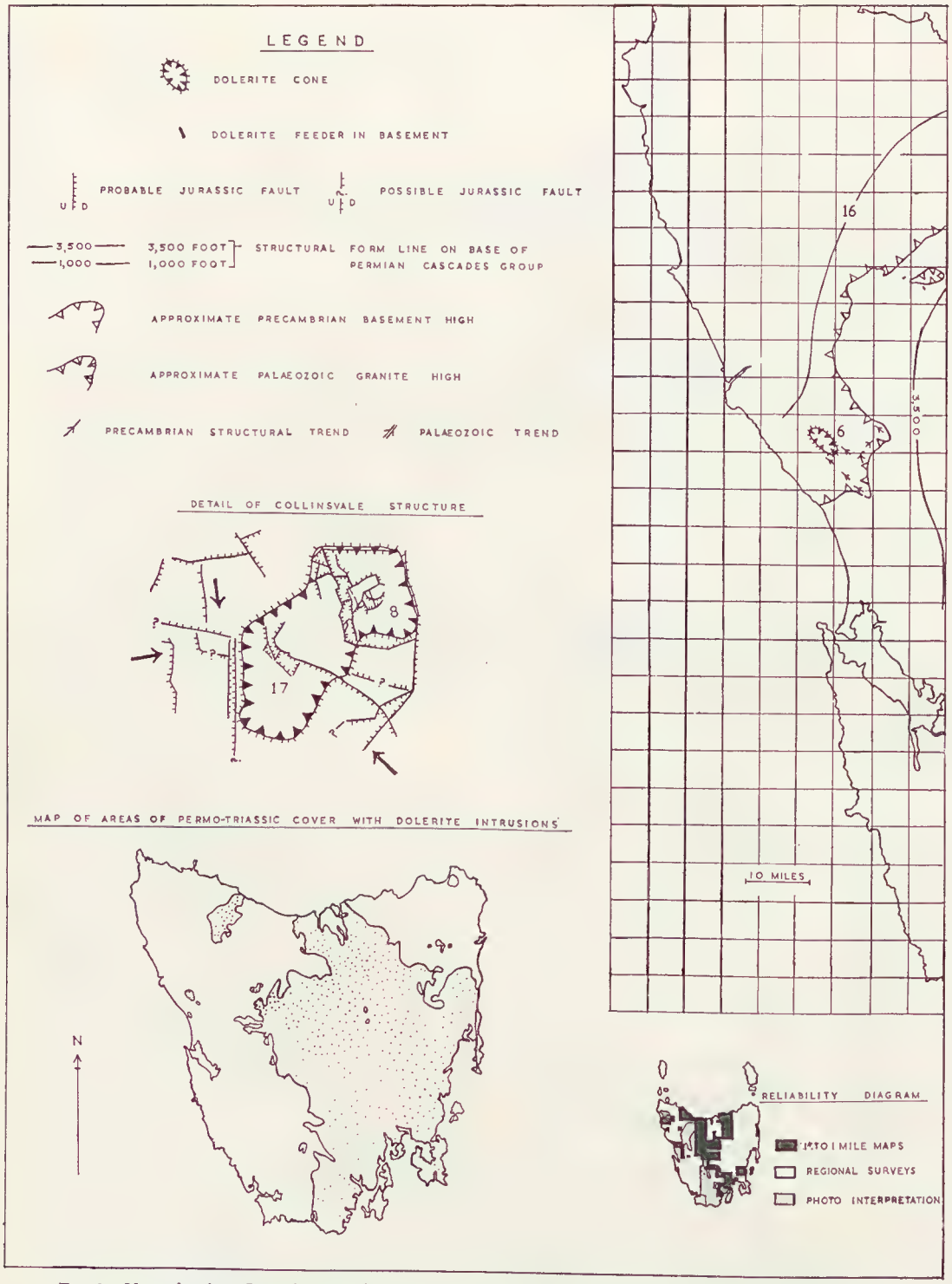

FIG. 2.—Map showing Jurassic tectonic features, including distribution of known dolerite feeders and cone structures, faulting, and structural highs. *1.* Great Lake Structure; *2.* Huon Structure; *3.* Esperance Structure; *4.* Billop Structure; *5.* Golden Valley Structure; *6.* Zeehan Structure; *7.* Bloomfield Structure; *8.* Collinsvale Structure; *9.* Patersonia Structure; *10.* Cheyne River Structure; *11.* Mangalore Structure; *12.* Little Denison River Structure; *13.* Tiers Fault Line; *14.* North-West Bay-Cascades-Dromedary Fault Line; *15.* Tyennan Geanticline; *16.* Rocky Cape Geanticline; *17.* Collinsvale Basin Structure at convergence of sill bodies (arrows).

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8. Collinsvale Structure (Sutherland, 1964): This structure shows most of the characteristics of a conical feeder, namely 1, 2 (in part), 3, 4, 5, 6 and 8. Limited investigation also showed the structure to be compatible with characteristic 9. In regard to characteristic 2 the north-eastern outer margin of the cone S.E. of Abbottsfield is shown on other mapping (see Banks, 1965) as a vertical contact displaced slightly southwards by a Tertiary downthrow to the north-east. This implies a slight outward dip of the dolerite margin. Careful examination at this place by the writer, however, showed the margin to slope slightly inward and meet the Tertiary fault a few yards to the south of the contact on the downthrown side. It is perhaps also worthwhile to record a further example of characteristic 4, just to the south of the mapped area. Here Triassic sandstones and Permian Ferntree Mudstone are exposed underneath the dolerite by a branch of the Mountain River and are dilationally downthrown of the order of 1,000 feet with respect to the rocks within the cone.

9. Patersonia Structure (Longman, *et al.*, 1964): Regional mapping here has revealed a structure showing characteristics 1, 3 and 6 suggesting a possible cone-like feeder.

10. Cheyne River Structure (Gulline, 1965): A dolerite centre here shows characteristics 1, 2 (in part), 3, 4 and 6, and is suggestive of a cone-like feeder, although the root zone is not exposed.

11. Mangalore Structure: The structure has been mapped by Nye (1922), Lewis (1946), and McDougall (1959). The latter writer suggested the dolerite mass at Strathalie Hill was possibly an intrusive centre. It is suggested here the structure is possibly a cone-like feeder extending from Strathalie Hill to Wybra Hall (Figure 1).

The dolerite encloses a sedimentary block (characteristic 2, in part) and isostrats conform with characteristic 3. The inner margin of the southern wall of the structure was observed by the writer in a quarry north-west of Goat Hill. Here it is clearly seen sloping inward to the north at about 75 degrees. The outer margin of this wall extends outwards forming the sill body to the south and probably transgresses gently upwards through the Triassic strata. This is not immediately apparent as the dolerite on the southern side of the Jordan River is in places at a lower level than the dolerite of Goat Hill. This can be accounted for by the eight to ten degree tilt of the strata here, probably mostly due to tilting toward the Dromedary Fault plane during the Tertiary epeirogeny. McDougall considered the northern inner margin of the structure represented the top of the dolerite sheet sloping to the south underneath the sedimentary strata. The writer has observed dolerites of the upper differentiation zone at this contact, along the Broadmarsh Road one mile from Mangalore, confirming this interpretation (characteristic 8).

The sedimentary block enclosed by the dolerite is dilationally uplifted with respect to the rocks outside (characteristic 4) and is expressed physiographically as a basin (characteristic 5). This is most apparent near Wybra Hall. The northern dolerite-Triassic contact here was mapped by McDougall as a possible extension of the Tertiary Bagdad Fault, but he suggested it was probably an intrusive contact due to the presence of sandstones metamorphosed to quartzite. McDougall's map however, shows little apparent differential displacement at the western end of the structure. Check mapping by the writer proved the small area between the basalt plug and the dolerite margin about one mile north-west of Goat Hill, to be Ferntree Mudstone and not Triassic sandstone as shown by McDougall. The break in rock type is probably due to a fault, concomitant with the dolerite intrusion and down-throwing to the north-east. This was apparently the line of ascent of the Tertiary basalt plug, and its presence brings Ferntree Mudstone within the dolerite up against Triassic rocks on the outside. In association with the concomitant faulting there is strong updragging, shattering, and thermal metamorphism noted by McDougall along the intrusive contact at Strathalie Hill (characteristics 6 and 7).

A noticeable feature of the Mangalore structure is the much greater thickness of the dolerite to the west and north than to the south and east (see Figure 1). One possible explanation is that the sill-body, intruded low down in the Permian beds and brought to the surface on the upthrown side of the Dromedary Fault, originated from the southern part of the structure, tapping much of the dolerite magma from that part. Finally, although this structure shows many of the characteristics of a cone-like feeder, alternative structures are possible. A knowledge of the depth of the sedimentary block enclosed by the dolerite, such as might be gained from a geophysical survey, would help to indicate: (i) whether the dolerite is rising from a basement feeder; or (ii) whether the structure is merely a large sedimentary block rafted up above a low-level sill rising from the south-west.

12. Little Denison River Structure: The south-eastern end of this structure has been mapped by Ford (1955). Examination of this and the aerial photograph interpretation mapping to the north-west (Geological Map of Tasmania; Tasmanian Department of Mines, 1961) indicates characteristics 1, 2, 3, 4, 5 and 6, suggesting a possible cone-like feeder. Detailed mapping of the north-western section of the structure will be necessary to prove this.

Other Possibilities: Some other structures that have been mapped exhibit some of the characteristics associated with conical feeders and may prove to be so with further investigation. These include the structure south of Boyer (Woolley, 1959) and the structure east of Lindisfarne (Hastie, 1961). Banks (1958) suggested that the dolerite near Takone possibly represented a cone sheet. Recent mapping in this area, however, has shown the structure to be essentially a flat-lying concordant sill rising from a dyke-like body in the northern part (R. D. Gee, pers. comm.).

Large tracts of dolerite country in Tasmania are still incompletely known, particularly on the southern and eastern coasts. Further conical structures may be recognised with detailed mapping. Some of the plug-like bodies exposed in the folded basement may represent feeder channels of cones now completely denuded.

FORM OF THE CONE STRUCTURES

The cone-like structures of Tasmania are generally asymmetrical. Most are elongate in plan. They commonly have a north-westerly orientation, but some have a tendency to an east-west orientation (Figure 2). The Collinsvale structure at first sight is elongate north-easterly but its throat east of Glen Lusk has a north-westerly orientation. In sections one side of the cone is generally steeper than the other and is commonly almost vertical (Figure 1).

These structures present some difficulty in regard to interpretation of the mode of emplacement. As has been shown, in many instances, there is insufficient evidence to determine whether they represent rootless conical sheets, emplaced under the flotational mechanism of Bradley (1965), or whether they represent conical feeders as suggested by Carey (1958a). Indeed, examples of both posisbilities may be present. Where the intrusions are associated with concomitant radial and peripheral faulting, with strong fracturing of the roof rocks, and with strong thermal effects, &c. (e.g., Collinsvale, Huon and Bloomfield structures), they would seem to represent centres of intrusion. However the alternative case cannot be completely discounted as similar fracturing, &c., possibly may result from: (1) a building up of intrusive pressure associated with downward flow of dolerite, collecting where a compensation surface forms an angular pocket; and/or (2) cauldron subsidence as the emplacement of the dolerite magma continues by upstepping to higher levels. In this event it would be expected that the fracturing would be mostly confined to the roof rocks. This does not appear to be the case with the Bloomfield and Huon structures, at least.

If the Tasmanian structures mainly represent conical feeders, then most of them differ in form from the classical Hebridean cone sheets (Anderson, 1942) in several particulars. They differ in being unsymmetrical in section; in the limb angles (one limb generally being steeper and the other shallower compared with the classical case); in not forming concentric series; and in showing greater thicknesses of dolerite. Carey (1958b) has discussed how thicker, and more shallow-limbed, cone sheets than the classical types can arise where conical feeders intrude young sedimentary layers. This results from the tendency to flotational intrusion counteracting the conical shearing due to the hydrostatic head of the intruding magma. Some of the Tasmanian structures may be of this type (e.g., the Bloomfield structure, as discussed later) but the marked asymmetry shown by most of the conical structures requires further explanation.

Examination of these structures indicates that the steep limb of the cone is emplaced along a fault and that the shallower limb, as a rule, intruded on the upthrown side of the fault (e.g., Collinsvale, Cheyne River, and Mangalore structures). Emplacement of dolerite along a fault would greatly reduce the effect of conical shearing due to the hydrostatic head of intruding magma and emplacement by flotational intrusion would be the dominant intrusive process. Under these conditions conical structures could develop as the result of sideward emplacement of tongue-like wedges of dolerite from the magma rising along the feeder fault. Bradley (1965, fig. 5) illustrates the stress conditions at the apex of such a wedge and shows that there will be a tendency to tensional fracturing of the roof rocks in a plane inclined to that of the wedge. Thus, with a circular tongue-like wedge there will be a tendency to form a conical fracture around its margin. Bradley also notes (*loc. cit.*, p. 36) that in the early stages of intrusion, when such a wedge is fairly small in area, the magmatic pressure may be raised considerably by the load of the over-hanging roof. Such conditions would favour cone-like extension of the dolerite wedge, accompanied by peripheral and radial faulting of the intruded strata. As the wedge extended there would be a decrease in magmatic pressure. The course of the intrusion, then, would be influenced more by other controls, such as bedding planes and compensation surfaces, and there would be reduced breaking of roof rocks. The tendency to initial cone-like extension of tongue-like wedges will depend on the shape of the wedge in plan, and will decrease proportionally with the departure from a circular plan. Thus, there will be a range of possible structures from almost circular cone-like bodies, through increasingly elongated types, and finally to sill-like bodies. Even in instances where there is little or no tendency to conical fracturing by an intruding dolerite wedge, a conical structure may still ensue as the result of intrusion along a conical compensation surface.

Bradley (1965) remarks that the factors controlling the horizon at which initial sideways emplacement of a wedge takes place from a dolerite feeder are probably largely fortuitous. However, where the dolerite feeder dykes rise along a fault there is probably a tendency for a wedge to intrude initially on the upthrown side. This would result from an upstepping of compensation surfaces on downthrown sides of young faults (Bradley, 1965). This is illustrated in Figure 3 and would account for the asymmetrical profiles of many of the Tasmanian cone structures. The Mangalore structure (Figure 1) may represent the case where this tendency was only partly realized. Thus, there was emplacement of a sill wedge along a particularly favourable lower horizon on the downthrown side, in addition to the emplacement of the wedge on the upthrown side. Where rootless conical sheets, emplaced along compensation paths, meet young faults they may show similar asymmetrical upper profiles to those of conical feeders emplaced as detailed above. This again stresses the difficulty in determining the mode of emplacement of some of the cone-like structures where there is lack of evidence regarding the nature of the root zone.

The majority of the Tasmanian cones appear to rise from below the level of the folded basement beneath the Permo-Triassic cover. The Zeehan structure, thus, rises from some distance within the basement and alternative explanations for this by Carey (1958a; 1958b) and Bradley (1965) have already been dealt with. The structure at Bloomfield is an exception in that it appears to rise from about the base of the Triassic succession. This structure has been interpreted as a conical feeder (Anand Alwar, 1960) and, if so, then it is

presumably a secondary rather than a primary feeder. A possible source is the sill intruded into the Ferntree Mudstone and rising up into the base of the Triassic System, eight miles to the south-west. Some of the conical sheets of the Karroo dolerites of South Africa have been considered to have developed from cupola-like structures on sill roofs (see Walker, 1958). The Bloomfield structure appears to be centered in a domal structure in the Permo-Triassic rocks, with radial and peripheral faulting and is accompanied by cauldron subsidence; all of which is compatible with such an origin. That such cupolas do occur on sill sheets in Tasmania is indicated by the structural interpretation of the Red Hill dyke body by McDougall and Stott (1961). It is interesting to note that the dolerite has differentiated to granophyre at both the Red Hill and Bloomfield structures. The possibility exists that a cone sheet structure was also originally developed on top of the Red Hill dyke, with perhaps another on the similar structure at Hickman Hill to the north. Evidence for this has been mostly destroyed by erosion. However, there is a dolerite sheet, to the east, capping Mt. Louis and sloping to the south-east, but on its western margin arching over and shelving downward towards both Red Hill and Hickman Hill.

The Bloomfield structure raises some interesting points regarding its mode of emplacement. As mentioned previously, it is considered unlikely to be a rootless conical sheet, emplaced along a conical compensation surface that would exist here complementary to the domal high. However, its emplacement as a shallow conical feeder, formed from magma rising from an underlying cupola-like reservoir, may have been largely guided by such a compensation surface. Alternatively, the cone may have resulted from the mechanism outlined by Carey (1958b) for conical intrusion in young sedimentary layers. The stratigraphic level of intrusion at Bloomfield, and also that of a possible similar structure at Red Hill, appears to be at about the base of the Triassic System and may be of significance. This horizon would consist of less consolidated sediments overlying slightly more consolidated and folded (warped) Permian beds. Under the intrusive mechanism of Carey (*loc. cit.*) it would bear the same relationship to a magma reservoir, but to a lesser degree, as would the unfolded Precambrian-Palaeozoic basement to its Permian cover. In the former case the magma reservoir was probably a sill-cupola, in the latter case subcrustal.

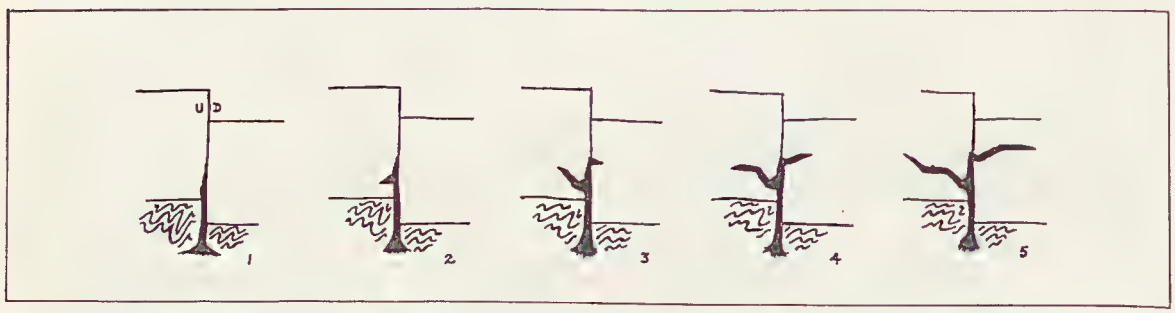

FIG. 3.—Diagrammatic representation of successive emplacement of dolerite (black) intruding along a fault, and giving the typical asymmetrical section as shown by some Tasmanian cone structures.

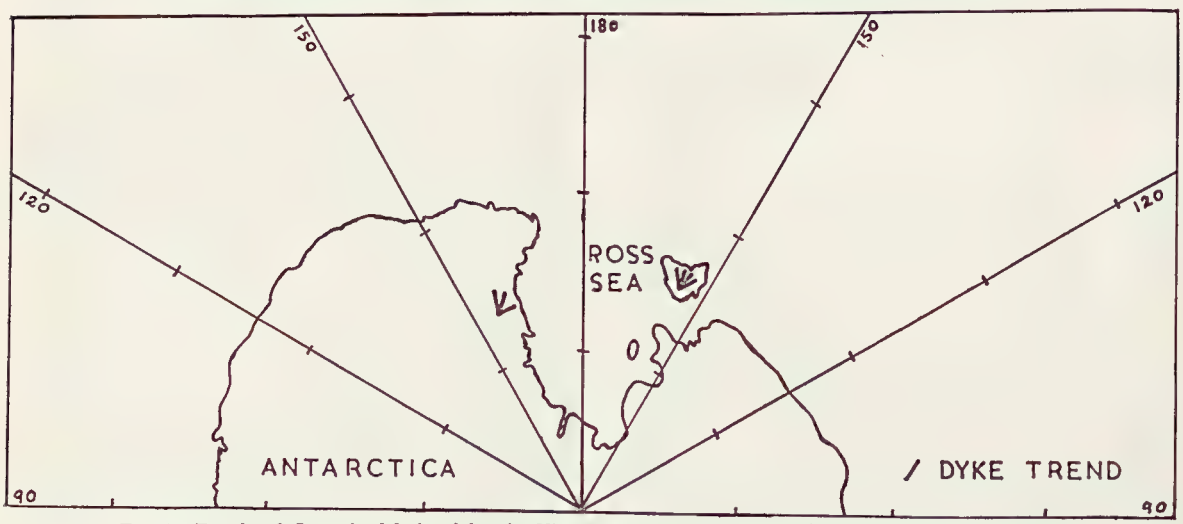

FIG. 4.—Trends of Jurassic dolerite dykes in Victoria Land, Antarctica (from Gunn and Warren 1962) compared with those of Tasmania (Banks 1958). Tasmania is restored to its probable location in the Jurassic.

TECTONICS OF THE DOLERITE INTRUSIONS

A knowledge of the structure of Tasmania prior to the intrusion of the dolerite is important in understanding the control of its emplacement. Banks (1962) has suggested epi-Permian uplifting in eastern, north-eastern and western Tasmania. The evidence he gives for this is further supported by the presence of Permian rocks in a conglomerate bed in the upper beds of the Triassic System (Nye, 1921). Banks (*loc cit.*) shows the Permian beds were folded into a major north-north-westerly synclinal structure that provided a basin of deposition for the Triassic freshwater succession. The main uplifted areas are outlined in Figure 2, in this paper, by the plot of the 1,000 foot and 3,500 foot structural form lines on the base of the Permian Cascades Group. Also plotted are the approximate margins of highs in the old Precambrian basement, relevant areas of the Palaeozoic highs, and the structural trends in these areas.

All recognisable cone structures, basement feeders and faulting associated with the dolerite intrusions are also plotted on Figure 2. The data has been compiled from the published detailed mapping of the State. This includes the Geology Department, University of Tasmania, 1 inch series; the Tasmanian Department of Mines 1 mile series, as well as maps in the Geological Survey Bulletins, Geological Survey Mineral Resources, and Technical Reports; mapping for the Hydro-Electric Commission in published papers in the Royal Society of Tasmania; and other incidental publications. Information was also used from unpublished maps of the Geology Department, University of Tasmania 1 inch series and from recent mapping by R. P. Mather, Hydro-Electric Commission, and R. D. Gee, Tasmanian Department of Mines. Early regional mapping published by the Tasmanian Department of Mines in the Geological Survey Bulletins, Geological Survey Mineral Resources and Underground Water Supply Papers was also used, but is generally insufficient to determine Jurassic structures. A reliability diagram is shown in Figure 2. Responsibility for the interpretations of Jurassic features from the above sources, and shown in Figure 2, rests with the writer.

It must be borne in mind that Figure 2 is not a complete representation of the Jurassic tectonic structure. This is due to the unfinished detailed mapping of the State, the lack of evidence as to the form of some of the dolerite bodies, the lack of evidence as to the precise age of many of the post-Permo-Triassic faults, the difficulty in recognising faults in lithologically similar strata, and the absence of exposures of the Permo-Triassic strata and dolerite structures due to denudation, mutual blanketing, or superficial deposits. Nevertheless, certain features concerning the emplacement of the dolerite are apparent.

Distribution of the Basement Feeders: One of the most striking features is the disparity in the concentration of the dolerite emplacement; by far the greatest density of dolerite and of exposed feeders being in the eastern two-thirds of the State. There is a lack of feeders in the areas enclosed by the 3,500 foot structural form line.

The cone-like structures are situated mostly along the margins of the main uplifted highs of pre-dolerite Tasmania or on smaller highs between these. In some cases these correspond to Precambrian basement highs. Thus the little Denison, Cheyne River, and Great Lake Structures are located along the eastern margin of the Tyennan Geanticline, the Zeehan structure along the eastern margin of the Rocky Cape Geanticline, and the Golden Valley and Billop structures on the flanks of narrow north-westerly trending Precambrian ridges. The Patersonia structure is sited on the margin of the north-eastern pre-dolerite high of Palaeozoics. Other cones are located on apparent highs in the Permo-Triassic strata. The Huon structure is centered in a domal structure (Banks, 1962). Whether this is controlled by an underlying local basement high, or whether it is due to the dolerite intrusion, has not yet been established. The Collinsvale structure appears to be sited on the flank of a north-west-northerly trending anticlinal structure following, and lying west of, the Cascades Fault line (see Banks, 1965). This structure may represent an underlying basement ridge or margin, as there is evidence, discussed later, that the Cascades Fault is pre-Collinsvale structure in origin, downthrowing to the north-east presumably with a corresponding drop in the basement.

The basement feeders on the flanks of the main pre-dolerite highs are dominantly plug or dyke-like plug structures. Examples are numerous and include plugs at Long Lake (MacLeod, Jack and Threader, 1961), Devil's Gullet (Ford, 1960; Jennings, 1963), Ringarooma (Nye, 1924a) and St. Patricks Head (McNeil, 1965). In contrast in the downwarps between the highs, long dyke-like structures (megadykes), transgressive sill-bodies and numerous rafted blocks of sediment are very characteristic. Numerous examples occur in the Midlands (Nye, 1921; 1922; 1924). The nature of the feeders in the basement for these structures is nowhere exposed, but it is difficult to visualise how they could arise unless fed by long feeder dykes.

Faulting Associated with the Dolerite Intrusions: The dolerite intrusions were controlled by, and also caused, extensive Jurassic faulting. Criteria for the recognition of Jurassic faulting in Tasmania have been discussed by Carey (1958a) and Banks (1958). The Jurassic fault pattern shown in Figure 2 is the result of the applications of these criteria to the available geological mapping of the State. The incompleteness of this pattern has already been stressed. In many cases it is not possible to determine whether the faults affect the basement or are merely breaks in the sedimentary cover resulting from intrusive dilational phenomena associated with the dolerite. Furthermore, the present relative movements shown on the faults are not necessarily the original sense of movement. This may result from later reverse movements associated with dilational phenomena of intruding dolerite or Tertiary epeirogenic movements (see Carey, 1958a). However, some tentative conclusions regarding the Jurassic faulting can be made.

Some, at least, of the major Tertiary faults of the State were originally lines of Jurassic movement. This has already been suggested for the Tiers Fault (Carey, 1958a). There is also evidence that the North-West Bay-Cascades-Dromedary Fault line is a pre-dolerite feature. The grounds are: (1) the fault line appears to be interrupted and displaced by the intrusive dolerite of the Ridgeway-Mt. Nelson's area; (2) the dolerite of the Red Hill-Hickman Hill-Picket Hill body appears to rise from the North-West Bay Fault, east of which it is either absent or at a considerably lower stratigraphic level (McDougall and Stott, 1961); (3) at Chigwell the outer margin of the Collinsvale cone-sheet structure is intrusive into the lower part of the Ferntree Mudstone on the western side of the fault, but on the eastern side is intrusive into beds of the Triassic System, suggesting a pre-intrusive downthrow to the north-east; and (4) at the north-western end of the Dromedary Fault, the Dromedary sill body is instrusive into Ferntree Mudstone on the western side of the fault, but on the opposite side the same sill body intrudes at least 650 feet above the base of the Triassic (McDougall, 1959), again suggesting a pre-intrusive downthrow to the north-east. Bradley (1965) has suggested that where dolerite bodies intrude across young faults they upstep on the downthrown side by an amount about seven times that of the throw of the fault. At Chigwell the eastern limb of the Collinsvale structure is near vertical and is intruded along the Cascades Fault, upstepping from low down in the Permian succession on the upthrown side to a considerable height in the Triassic succession on the downthrown side. Applying Bradley's dictum, this suggests a pre-dolerite throw of at least 350 feet. Similarly, a lesser throw is implied along this fault line at the north-western end of the Dromedary Fault, and is of the order of 100 feet.

The faulting in places suggests the development of horst-like and graben-like structures in the down warps between the main pre-existing highs. It also suggests that the Tertiary Midlands, and Cressy grabens are, in part, an inheritance from the Jurassic.

In the Tamar Valley Permo-Triassic strata show regional dips from both sides in towards the Tamar River, which appears to occupy the axis of a north-west-northerly downwarp (see mapping of Green, 1959; Marshall, 1965; and Longman, *et al.*, 1964). This downwarp does not continue much further south of the Tamar River where westerly regional dips continue to Poatina. There has been Tertiary tilting and faulting, but this structure does not seem to be completely explained by the known Tertiary faulting and may be partly a Jurassic structure. A long dolerite body is intruded on the west side of the Tamar River and dips steeply to the north-east. Just south of Blackwall the writer has observed steep downdragging in the Triassic(?) strata at the intrusive contact. Similar downdragging is also observed at Long Point where Green (1959) records a dip of 68° to the north-east. This suggests intrusion along a Jurassic fault line downthrowing to the north-east. If this interpretation is valid then it would appear that the Tertiary Tamar trough structure may also be partly inherited from Jurassic times.

The fault pattern in southern Tasmania is very complex. There appears to be a graben structure bounded to the west by the North West Bay-Cascades-Dromedary Fault and occupied by a complicated horst-like structure extending from Storm Bay to Grass Tree Hill. Whether the Tertiary Derwent graben was initially a Jurassic structure is not clear. Some of the Jurassic faulting parallels the trends of the main Tertiary faults, some of which, then, may represent movements along old Jurassic lines. Similarly there is also the possibility that the Tertiary Oyster Bay graben is, in part, Jurassic in origin.

There is some suggestion that the pattern of faulting was controlled to a certain extent by the margins of the main pre-existing basement highs and their associated structural trends. The complicated fracturing in the southern part of the State is possibly partly due to superposition of differing trends in the basement as can be seen to the west where the Palaeozoic trends oppose those of the Precambrian. In the northern part of the State these trends generally coincide and appear to be matched by the Jurassic trends.

The Jurassic tectonic pattern is as yet too incomplete to give a coherent picture of the stress environment but it is suggested north-east to east-north-easterly tension was important. Tensional stress in this direction is compatible with the elongation of many of the dolerite cone structures and the orientations of many of the megadykes. It is also noticeable that where the margins of the pre-dolerite highs and the trends in the basement rocks are co-incident with each other, and are normal to these tensional directions, as in northern Tasmania, there tends to be a corresponding parallelism in the Jurassic faulting and the pattern appears less complex than elsewhere.

EMPLACEMENT OF THE DOLERITE

The following synthesis of the emplacement of the Tasmanian dolerites is presented, arising from the foregoing discussion concerning the pre-dolerite structure, the nature and distribution of the dolerite cones and feeders, and the associated faulting.

Prior to the emplacement of the dolerite, and as a result of epi-Permian uplifts, Tasmania consisted of a cover of Permo-Triassic strata draped in downwarps between highs in the east, north-east, and west, and between lesser intervening highs. Normal faulting under Jurassic tensional forces, including north-east to east-north-easterly tension, developed in the downwarps between the uplifted highs, probably with development of graben and horst-like structures. Fairbridge (1949) has pointed out that it is in such downwarps that the basement fractures first under tension, rather than in the highs. Dolerite magma rose up along these feeder fractures. Where the margins and structural trends of the basement highs coincided and were normal to the main tensional forces there was a corresponding parallelism in the faulting. Where the margins and/or structural trends were opposed to each other and to the main tensional forces the faulting, and consequently dolerite intrusion, was more complex.

The greatest fracturing probably occurred in the central trough of the main downwarp between the western and eastern uplifted highs. Dolerite would ascend mainly through long feeder dykes. Compensation surfaces (Bradley, 1965) beneath this downwarp would occur as steepening arches with numerous vertical jumps across young faults. Thus, dolerite sills rising from feeders and following compensation paths would tend to be transgressive. Splitting of sills would also occur, due to alternative paths of intrusion being available as a result of divorces between compensation and bedding surfaces. Thus, rafted blocks would be a feature. Upstepping across faults would be common giving rise to numerous large dyke bodies (megadykes). All this seems to correspond well with the dolerite outcrop patterns in the Midlands and in parts of south-east Tasmania.

In the higher areas away from the downwarps there was reduced tensional fracturing. Old Precambrian-Palaeozoic structures probably played a greater part in guiding the ascent of the dolerite magma. as has been noted at Golden Valley (Sutherland, 1965) and near Takone (R. D. Gee, pers. comm.). In the broad view, compensation surfaces in the Permo-Triassic cover in these areas would tend to be correspondingly smoother and form flattening troughs, bottoming on the basement in areas of maximum uplift. Thus, in Tasmania the sill sheets tend to become correspondingly more extensive away from the central trough of the main downwarp between the western and eastern highs. Certain horizons proved more favourable than others for emplacement of sills. These were notably at about the level of the Grange-Malbina Formations in the Permian succession and above the Ross Sandstone in the Triassic sequence (see Fairbridge, 1949; Carey, 1958a). The extensive dolerite sill sheet that caps the Central Plateau, Upper Derwent and Upper Huon areas appears to generally conform in behaviour with the likely Jurassic regional compensation surfaces. Although showing exceptions due to the presence of dolerite feeder centres and locally imposed variations in the compensation surfaces, the dolerite shows a general downward transgression as it extends westward across the rising flank of the main pre-dolerite high in Western Tasmania. Thus, the dolerite descends from the Triassic succession into the Permian succession at about between the 2,000 and 2,500 foot structural form lines on the base of the Permian Cascades Group (Banks, 1962). It descends further and rests on basement rocks at about the 3,000 to 3,500 foot structural form lines.

Dolerite cones were emplaced apparently, mainly along the margins of the main downwarps, either on the lower flanks of the uplifted highs, or on lesser intervening ridges and highs. A complete explanation for this cannot be given at present due to uncertainties as to the mode of emplacement of many of these structures. If they mostly represent rootless emplacements of dolerite along conical compensation surfaces, then they express local domes and ridges in the pre-dolerite physiography (if in the Permo-Triassic cover), or depressions (if lying within the folded basement). Such physiographic features, in cases, probably were structurally controlled. Thus some of the asymmetrical cones with one of the limbs emplaced along a fault could represent a fault scarp with locally raised rims. However, it is considered that some, and possibly many, of the cones represent dolerite feeders. Assuming this, the apparent distribution of the cones can be accounted for as follows. The reduced fracturing in the highs compared to that in the downwarped areas resulted in greater resistance to dolerite intrusion. In these areas the dolerite would tend to intrude by conical fracturing where there was sufficient intrusive pressure to overcome resistance. This would be mainly in the thinner parts of the main highs, i.e., the marginal edges, and underneath the narrow and smaller intervening ridges and highs. The dolerite would exploit potentially favourable sites and weakness in these areas. Possible modes of intrusion of such feeders have been discussed previously. Some of the cones are emplaced in part along faults. Some are associated with structural highs (in cases with part emplacement along faults as well) and show concomitant radial and concentric fracturing. It has been pointed out that these highs would offer the greatest potential for relief of upward stresses by means of such fracturing (Sutherland, 1964). Again, if the structural highs were expressed physiographically, compensation surfaces would also favour cone-like emplacement. The respective roles of these and other factors in controlling cone emplacement is difficult to determine. Thus, the Huon cone is emplaced in a domal structure in the intruded sediments. This dome may represent control of the site of intrusion by a local pre-existing structural high, or itself have resulted from the intrusion of the dolerite. Even if the initial emplacement of the cone was not controlled by conical compensation surfaces that would exist here, it is probable that compensation influences came into play. The Scott Arch (Carey, 1958a) is probably an expression of this, with emplacement occurring along a compensation surface complementary to the peripheral low surrounding the domal high.

On the upper flanks of the main high areas dolerite feeders intruded as plugs and dyke-like plugs. Here the intrusive pressure of the dolerite was apparently insufficient to overcome the greater resistance to intrude as cone-like structures. Dolerite rising from these feeders, and from the plug, dyke, and cone feeders on the lower flanks of these highs, joined with the dolerite rising from the more intensively fractured downwarps. At Collinsvale there is some suggestion that the cone was intruded slightly later than dolerite rising from the surrounding areas. Dolerite sills rise toward the cone from the north-west, west, and south-east. These sills converging on this spot appear to have wedged up the strata before them into the Collinsvale basin structure (see Figure 2). On the north-east side of this basin structure small slivers of Permian rocks near Abbotsfield (see Banks, 1965), in association with the Jurassic Glen Lusk and Hull Faults (Sutherland, 1964) outline a small down faulted block. This block occurs where the strata would remain unlifted by the wedging action of the approaching sill bodies. The action of such wedging is illustrated by Bradley (1965, figure 4). These faults and the adjacent basin structure have

controlled the Collinsvale intrusion and thus presumably antedate it. The Collinsvale structure is considered to have resulted from dolerite magma intruding up along the Cascades Fault at this spot, or from beneath the anticlinal ridge that flanks the Fault just to the west.

Secondary feeder cones probably developed on underlying sill bodies, as exemplified by the Bloomfield structure and possibly the Red Hill structure. These were apparently derived from laccolithic structures on the sills. Their emplacement may have been controlled by the nature of the Permo-Triassic boundary and/or by conical compensation surfaces that would exist complementary to the laccolithic doming.

Where the basement in the main highs exceeded heights of about 4,000 feet above its level in the downwarped areas, dolerite, apparently, was not intruded through the basement to any extent, and there is a lack of feeders in these areas. This, possibly, may be related to the lesser tendency to tensional fracturing in these areas, to insufficient intrusive pressure of dolerite to allow penetration, and to lowering of isogeotherms beneath the thicker parts of the basement highs.

COMPARISON WITH THE DOLERITES OF ANTARCTICA

Early Mesozoic palaeogeographic reconstructions show Tasmania as part of southern Pangaea or Gondwanaland continents at the time of the dolerite intrusions (Wegener, 1924; du Toit, 1937; King, 1958; Carey, 1958, &c.). The Tasmanian dolerites chemically closely match the Ferrar Dolerites of Antarctica (McDougall, 1962) and reconstruction of the southern land mass by Carey (1958) places Tasmania south of the Antarctic Circle, just east of the Ross Sea. This position accords with the dating of 167 million years for the Tasmanian dolerites (McDougall, 1961) in relation to datings of Ferrar dolerites which are 150-158 million years at latitudes south of Victoria Valley, 159-163 million years at the latitude of Victoria Valley, and 175 million years at the latitude of the north coast of Victoria Land (Webb and Warren, 1965). It is thus of interest to compare the emplacement of the Tasmanian dolerites with those of Antarctica.

The forms of the Antarctican intrusions have been described by Gunn and Warren (1962), Grindley (1963) and others. Sills were emplaced from dyke and plug feeders as in Tasmania, but were more extensive and the sill horizons more numerous. No cone structures have yet been described. The difference in mode of emplacement appears to be related to structural differences in the two areas at the time of dolerite intrusion. In Antarctica a cover of essentially horizontal beds of the Beacon Group (Devonian to Lower Jurassic) overlay a near-level peneplain (Kukri Peneplain) of folded basement rocks (Gunn and Warren, 1962). In Tasmania, on the other hand, the Permo-Triassic sedimentary cover overlay a more uneven basement, partly as a result of strong mid-Devonian folding (Tabberabberan Orogeny) and partly as a result of epi-Permian uplifts (probably associated with the Hunter-Bowen Orogeny). Neither of these events appear to have affected Eastern Antarctica. As a result Eastern Antarctica lacked the broad relief of Tasmania at the time of dolerite intrusion. Compensation surfaces would be much flatter and more continuous, resulting in the much greater extent of sill emplacement. The lack in contrast between downwarp fracturing on one hand, and reduced fracturing in highs on the other hand, would result in the lack of the Midlands type intrusion and the cone-like intrusions respectively. The development of secondary cone sheet structures at higher levels in Tasmania seems related to the presence of epi-Permian warping in the sedimentary cover. In areas where the basement relief became excessive in Tasmania, dolerite was not intruded. This may explain the scarcity of dolerite intrusions on the mainland of Eastern Australia, which was more strongly affected by the Hunter-Bowen Orogeny (Osborne 1950) than Tasmania.

Trends associated with Jurassic faulting and dolerite intrusion in Tasmania have been analysed by Banks (1958) but lack of information regarding those of Antarctica prevents a complete comparison. However trends of dykes in Victoria Land are reported by Gunn and Warren (1962). These are mostly north-east-northerly to easterly and in places, as in Tasmania, the emplacement of the dykes was guided by weaknesses in the basement rocks. The trends show some differences with the trends of maxima for dykes at 348-351°, 9°, 25°, and 38-41° in Tasmania given by Banks (*loc. cit.*). However, if Tasmania is restored to its probable position in Jurassic times, adjacent to the Ross Sea, then the Antarctican and Tasmanian dyke trends show closely similar orientations (Figure 4).

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Papers and Proceedings of the Royal Society of Tasmania, Volume 100

PLEISTOCENE DEPOSITS AT PARANGANA DAMSITE IN THE MERSEY VALLEY

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(With 3 text figures and two plates.)

ABSTRACT

Pleistocene glacial and periglacial deposits filling a channel 200′+ deep and 200′ wide at Parangana Damsite in the Mersey Valley are described. It is suggested that the site is the location of a terminal zone.

INTRODUCTION

The following information is the result of further investigation of Parangana Damsite (Figure 1) in the gorge tract of the Mersey River ½ mile below the Fisher River Junction. The results of a preliminary investigation were given in Volume 99 of this journal.

At the damsite (Figure 2, Plates I and II) the Mersey River is superimposed and flows from south to north transverse to the structural trend. The gorge has been cut in vertically to near vertically foliated Precambrian Fisher Group quartzite, schist, phyllite and slate. It has a broad upper profile and a narrow buried U-shaped central channel 200′+ deep and 200′ wide. The profile of the channel has been defined approximately by drilling and seismic survey. The average core recovery in the channel fill has ranged from 40% to 80% and these results have been achieved by using triple tube core barrels, bottom discharge bits and mud as the drilling fluid.

CHANNEL FILLING

Details of the channel filling are shown on Figure 3. The bottom of the channel has not been located, but the bulk of the channel from SL940′ to SL1125′ (185′) is filled with what is considered to be periglacial solifluction material. This is overlain by glacial drift, which has a maximum thickness of 50′.

The periglacial solifluction material is unstratified and consists of angular rock fragments in a yellowish to reddish-brown sandy clay to clayey sand matrix. Along the dam axis, where the valley walls are formed by quartzite, the angular rock fragments (Drill Holes 5773, 5774, 5781, 5782, 5783, 5784 and 5791) consists mostly of pebbles, cobbles and boulders (up to 18″ diameter) of quartzite, with pebbles 1″ and less predominating. A few angular pebbles of schist and rounded pebbles of weathered basalt and dolerite are also present. Downstream, where the valley sides are formed by repetitions of quartzite and schist, the proportion of schist pebbles (Drill Holes 5767 and 5771) is markedly higher. In both areas the ratio of fragments to matrix averages about 60:40. On the left abutment a pocket of periglacial solifluction material up to 90′ wide and 30′ deep occurs within the glacial drift (Drill Holes 5774, 5783 and 5791).

The position of this quartzite fragment and clay deposit below and within glacial drift suggests deposition close in time and place to a glacial environment, whereas the angular shape and the predominance of quartzite and schist fragments indicates local origin with little transport. Coupled with the similarity of the content of the deposit with the composition of the immediately adjacent valley wall this is indicative of a periglacial solifluction origin. The drill core has been examined by Stephens (Glacial Geomorphologist, Queens University, Belfast) who agrees with these conclusions. The mass movements are considered to have taken place when the glacier was in the near vicinity, as a result of thawing of the surface layer in the summer months while the ground below remained frozen. That the material accumulated and filled the channel suggests that it dammed it at a time when the flow of water was greatly reduced, when precipitation remained in the upper reaches of the valley in the form of snow and ice.

A distinctive reddish-brown clay occurs in the core from Drill Holes 5768 (82′-114′), 5772 (120′-125′) and 5784 (80′-97′). It is missing in Drill Hole 5782 which lies between Drill Holes 5768 and 5784. In this hole the clay is replaced by periglacial solifluction material containing a sand band (87′-91′), suggesting erosion of the clay. The clay may be the result of a solifluction slide of basaltic material from Emu Plains, or it may be a till, but most probably it was deposited in a lake dammed by a solifluction slide.

Bands of fine to coarse-grained quartz, quartzite and schist sand and gravel, ranging up to 11′ in thickness occur within the solifluction deposit, and the distribution suggests that some may extend laterally over about half the width of the channel. These are probably fluvial or fluvioglacial deposits laid down between slides. Drill Hole 5767 on the right bank encountered a 52′ channel cut into the upper surface of the solifluction deposit and this was also filled with quartz, quartzite and schist sand and gravel.

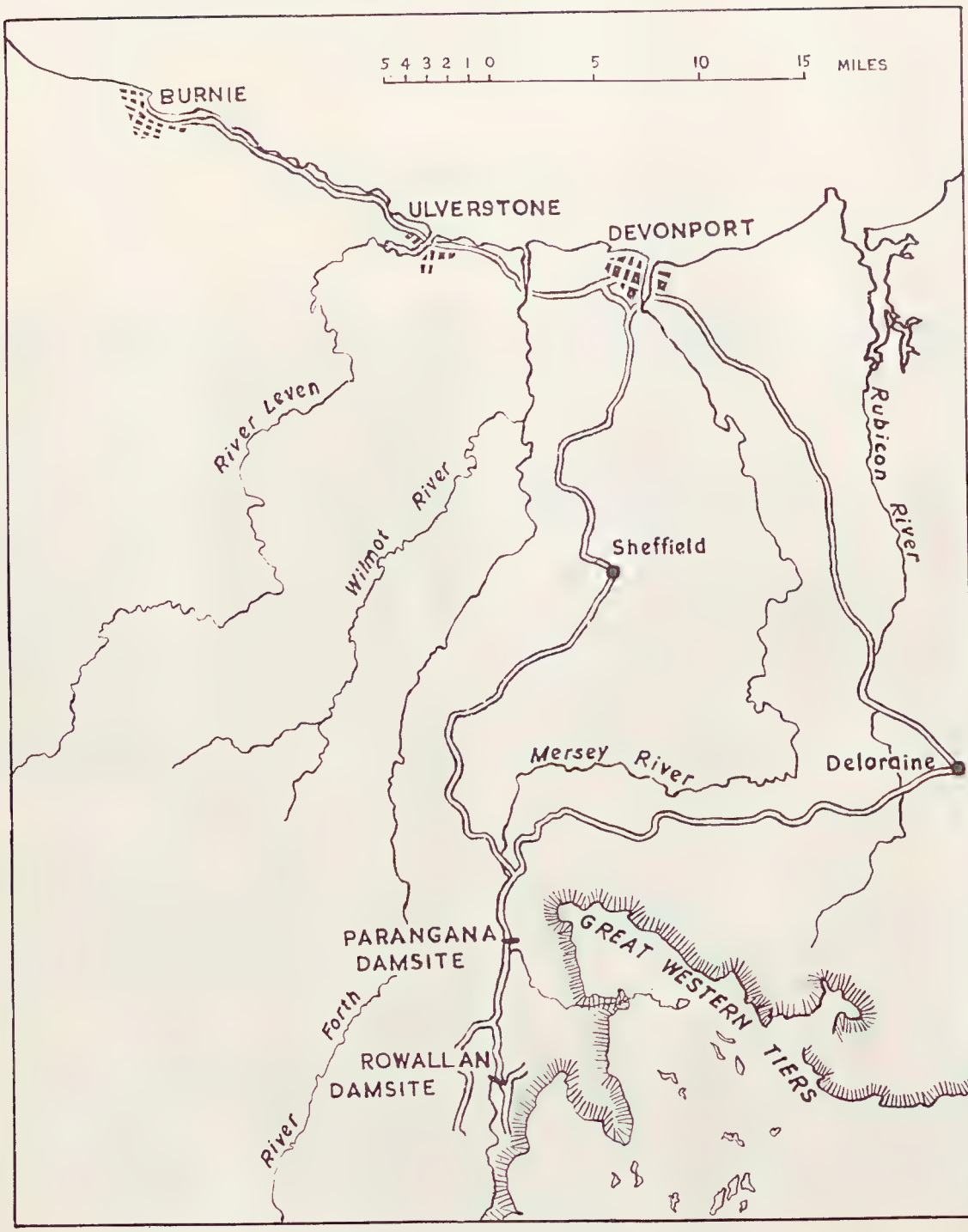

FIG. 1.—Locality Map.

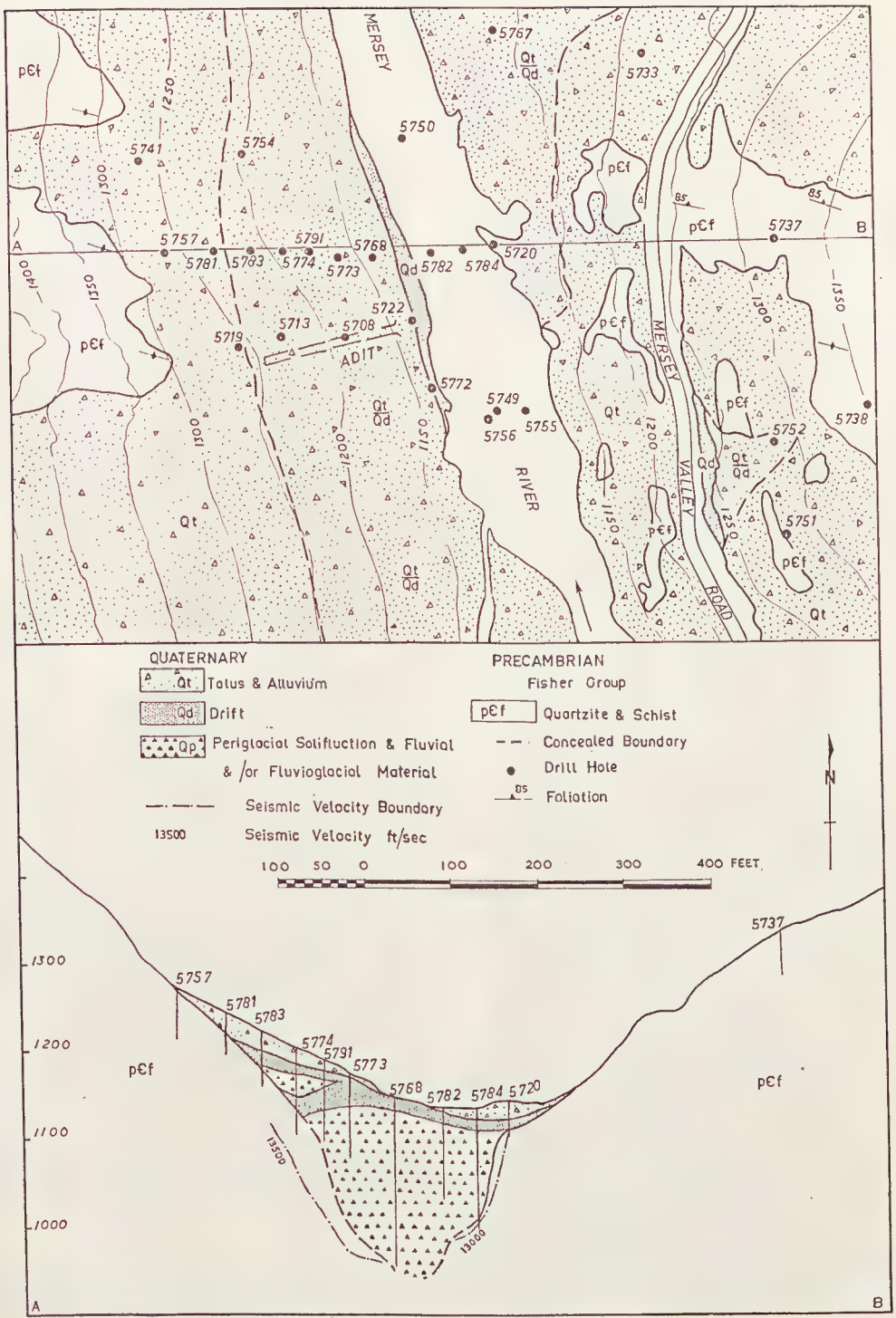

FIG. 2.—Geological Map and Section of Parangana Damsite.

GLACIAL DRIFT

The layer of glacial drift that covers the periglacial solifluction material extends onto both banks of the river, where it is in turn overlain by talus. The maximum thickness is about 50′ in the channel section, but a 20′ thick deposit occurs on the right bank 150′ above river level, and a 40′ thick deposit occurs on the left bank 130′ above river level.

An adit 110′ long was driven into the deposit on the left bank and in this up to 70% of the material consists of pebbles, cobbles and boulders, coated with clay, silt and sand. The material is toughly compacted, uncemented to weakly cemented, unstratified and heterogeneous, and the greater part has been derived from dolerite, with basalt, quartzite and schist contributing minor amounts. Boulders of dolerite and basalt up to 3′ in diameter occur and these are sub-rounded to rounded, whereas the boulders of quartzite and schist range up to 10′ diameter and are angular. The quartzite and schist boulders are locally derived, possibly superglacial till, but the dolerite boulders have been transported from the Central Plateau. The finer material is weathered yellowish-brown in the adit, but little matrix was recovered from the drill cores. Bands of medium grained quartz, schist and dolerite sand were located by Drill Hole 5772 (19′-19′6″ and 29′-34′) and the drilling mud was lost in Drill Hole 5773 at 29′-40′. It reappeared at the base of the slope 110′ downstream.

Subsequent river erosion has removed any topographic evidence of the nature of the deposit at Parangana Damsite. Nevertheless the drift appears to have been deposited near the limit of glaciation, for immediately downstream interlocking spurs replace the straight broad valley with truncated spurs that exists upstream of the damsite. The situation suggests terminal moraine conditions, such that both lodgment and ablation till might be expected. A degree of lithification corresponding to a weak tillite occurred in Drill Holes 5769 (47′-48′6″), 5770 (27′-31′) and 5771 (16′-20′) just off the northern edge of the Geological Plan (fig. 2) suggesting deposition as a lodgment till under a considerable weight of ice. By comparison the glacial drift in the adit is only a toughly compacted till, and the high proportion of coarse material suggests some washing by meltwaters and perhaps deposition as an ablation till. The presence of a pocket of periglacial solifluction material within the till suggests a retreat and readvance of the glacier. A high proportion of rounded pebbles and boulders occur in the till in the adit; this may be the result of weathering of the dolerite in the source area, the distance of transport (up to 20 miles), and reworking in part by water during transport.

The degree of weathering of the glacial drift at Parangana is unusually deep, for in the adit the matrix is weathered yellowish-brown at a depth of 85′ below the surface, which is 45′ below the base of the talus. Deep weathering also occurs at the Fisher River Junction where dolerite boulders are almost completely decomposed at a depth of 15′. By contrast the till in the Rowallan Damsite borrow area 7 miles upstream is fresh a few feet from the surface. Weathered material may have been transported by ice to the Parangana area from the upper valley, but the difference in degree of weathering may also be indicative of an age difference between the two deposits. The glacial drift at Parangana may be older than that at Rowallan Damsite.

TALUS

Talus obscures the greater part of the right abutment and all of the left abutment, and talus fans extend almost to plateau level on both sides of the prominent quartzite cliffs that lie above the left abutment.

The deposits have a maximum thickness of about 35′ (Drill Hole 5719) and slopes of up to 30°. Three test pits were dug on the left abutment and these indicate an upper few feet of loose rock fragments overlaying lightly compacted, tough, bony talus consisting of angular rock fragments set in a sandy clay matrix. The junction of the talus with the underlying drift is a free draining zone coated with black carbonaceous material.

The upper loose layer is moving under the existing environment but the thick compacted layer is considered to be the product of a periglacial environment and to have formed by solifluction (head) as the glacier retreated from the site. It is stable under the existing environment.

GEOMORPHIC HISTORY

The Mersey River took its present course (Spry, 1958) after extrusion of the Tertiary basalts, and at the beginning of the Pleistocene a valley about 1600′ deep was in existence. The nature of the basal deposits in the central channel is not known, but the profile indicated by drilling and seismic survey suggests some modification of the valley by glacial action. The central channel was filled by a series of solifluction slides, probably while a glacier remained in the near vicinity. During this period of reduced river flow the slides apparently effectively dammed the river permitting deposition of 32′ (Drill Hole 5768) of clay. The sand bands present are thought to be fluvial or fluvioglacial deposits laid down as the dams were overtopped. The presence of a pocket of solifluction material within the glacial drift suggests that at least two glacial advances occurred, at which time the solifluction deposits were protected from erosion by ground freezing. The location appears to have been near the site of a terminal zone.

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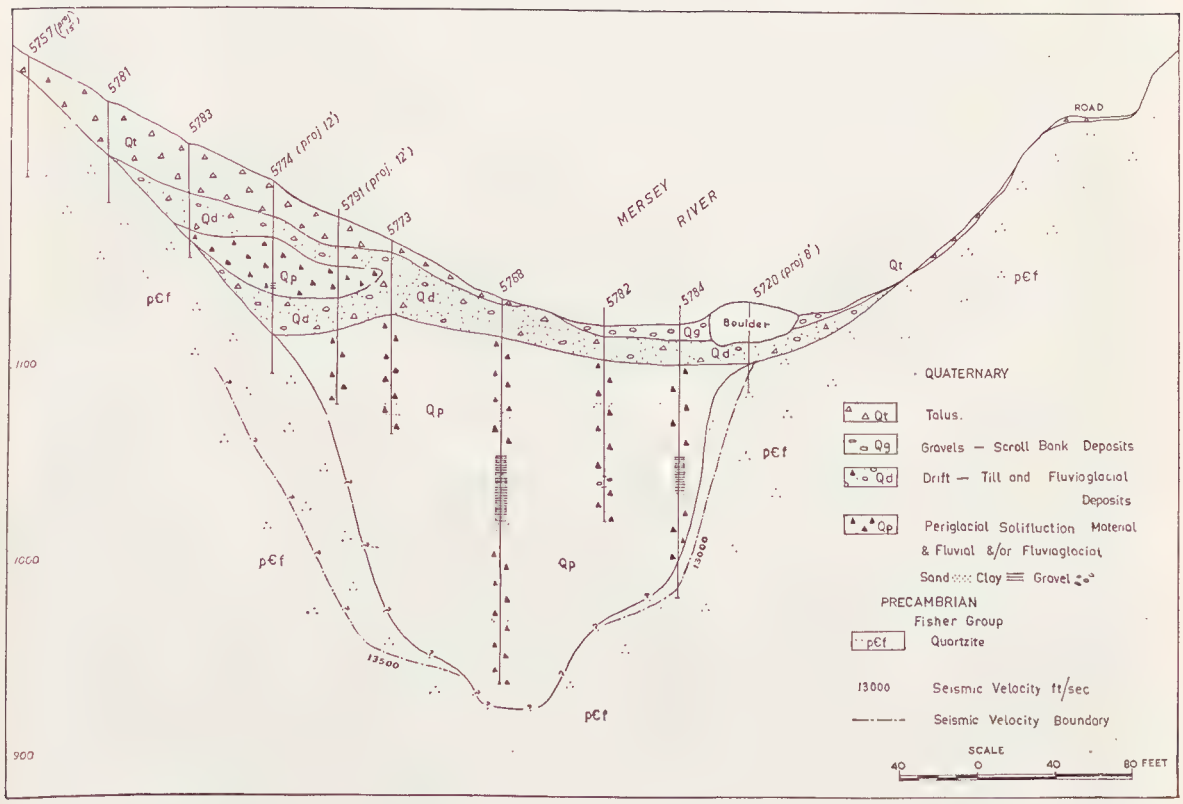

FIG. 3.—Details of the channel filling at Parangana Damsite.

Plate I.—The left abutment of Parangana Damsite showing cliffs of vertically foliated Precambrian Fisher Group quartzite (Q) and the talus slopes (S). The lower part of the talus covers glacial drift.

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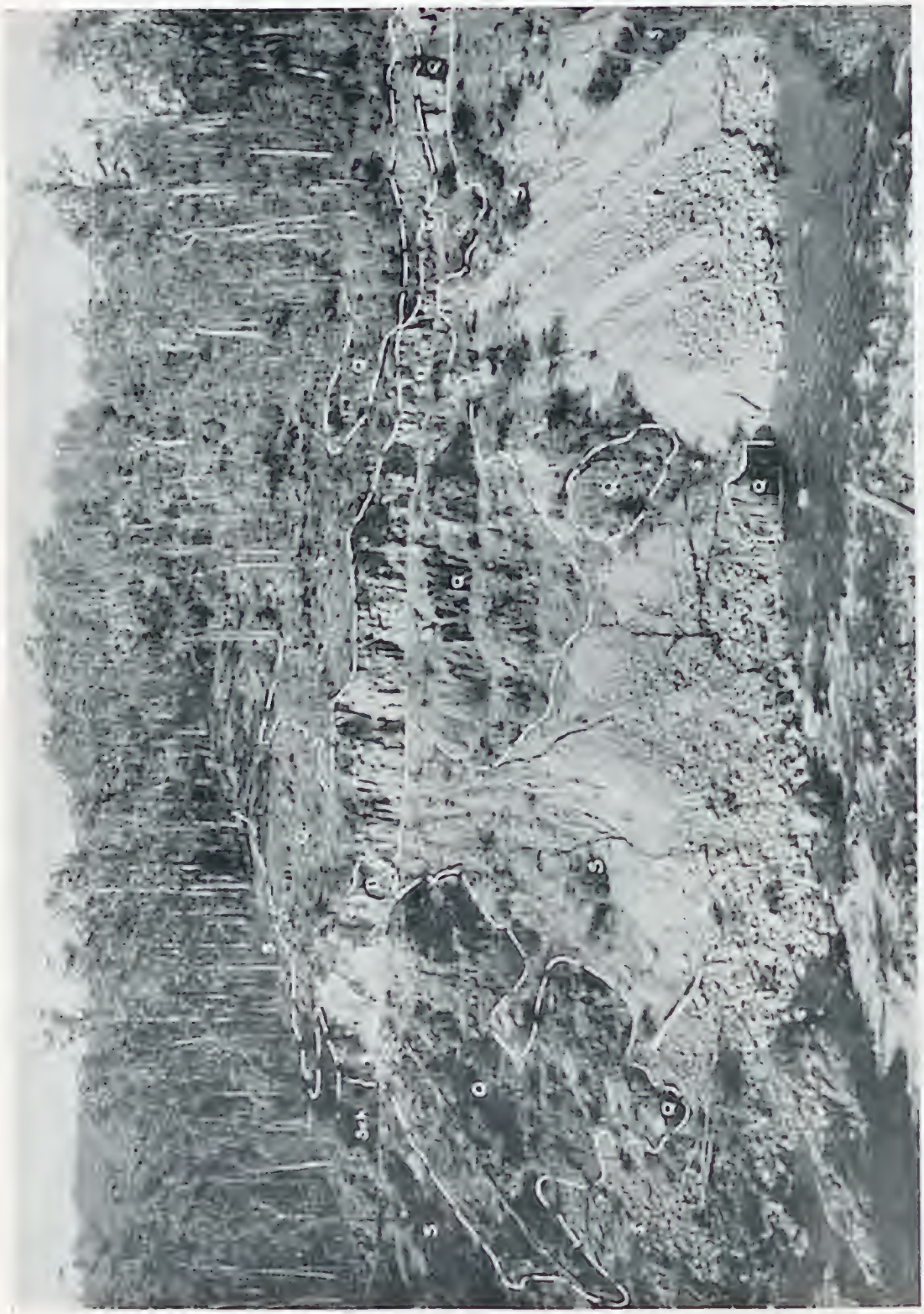

Plate II.—The right abutment of Parangana Damsite showing cliffs of vertically foliated Precambrian Parker Group Quartzite (Q), schist (Sch) and slate (Sl). Glacial drift (F) and talus (S) cover much of the lower part of the abutment.

Papers and Proceedings of the Royal Society of Tasmania, Volume 100

"OIL" ON FLINDERS ISLAND–BASS STRAIT

By

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(With one text figure.)

ABSTRACT

A survey has been made of the alleged occurrence of petroleum on Flinders Island, Bass Strait. An investigation of the material purporting to be petroliferous, has shown it to be a curious comminuted organic mass of plant detritus, apparently formed under unusual conditions.

The paludine "oil", and that produced by pyrolysis of the semipeat, is not related to mineral oil in any way. It is, on the contrary, a resinous, viscid decomposition product, composed of phenols, waxy esters, resins and an indefinite variety of organic residuals, to which the name plant adipocere might well be applied.

INTRODUCTION

Oily seeps, whether derived from petroleum or not, have often led sanguine prospectors to envisage potential oil finds, and, on many such occasions, quasi-fatty oils derived from elateritic or similar deposits have been confused with mineral oil. A case in point is that of Coorongite in South Australia, which has, in the past, given rise to a strong belief in the existence of petroleum in the area. Coorongite is, in fact, a partially decomposed fatty mass derived from the alga Botryococcus braunii (Conacher 1938).

Recently, the attention of the writer was drawn to a long-current belief on Flinders Island (Furneaux Group, Bass Strait) that there was a petroleum seepage there. The alleged petroleum was said to be associated with an elateritic deposit in a lagoon to the north-west of Adelaide Bay, at the south of the island. In the hope of finding Coorongite (it was thought unlikely that petroleum itself was present) a visit was made to Flinders Island, in February, 1965.

In view of the present interest in the search for petroleum in Bass Strait, it seems pertinent to place on record the exact nature of this "petroliferous" material and of the "oil" derived from it.

Discussion with local inhabitants confirmed that rumours of the occurrence of petroleum on the island had persisted for more than fifty years; in fact, in 1936, so strong was the belief in an impending oil boom, that the Austral Oil Drilling Syndicate was formed, with leases over 30,000 acres in the locality mentioned above. The occurrence of oily films on paludial waters in this area, and of two smoky fires in a nearby dry lagoon, one in 1913 which "burnt for years" and another about thirty years ago, no doubt gave rise to the persistent belief in the presence of petroleum. At one time, the Tasmanian Mines Department was persuaded to look into the matter and an interim report was made (Carey, 1945); somewhat earlier (Mines, 1932) the area was believed to be associated with oil shales.

A survey was made and, with the help of information from local farmers, the "oil field" was located, and samples obtained.

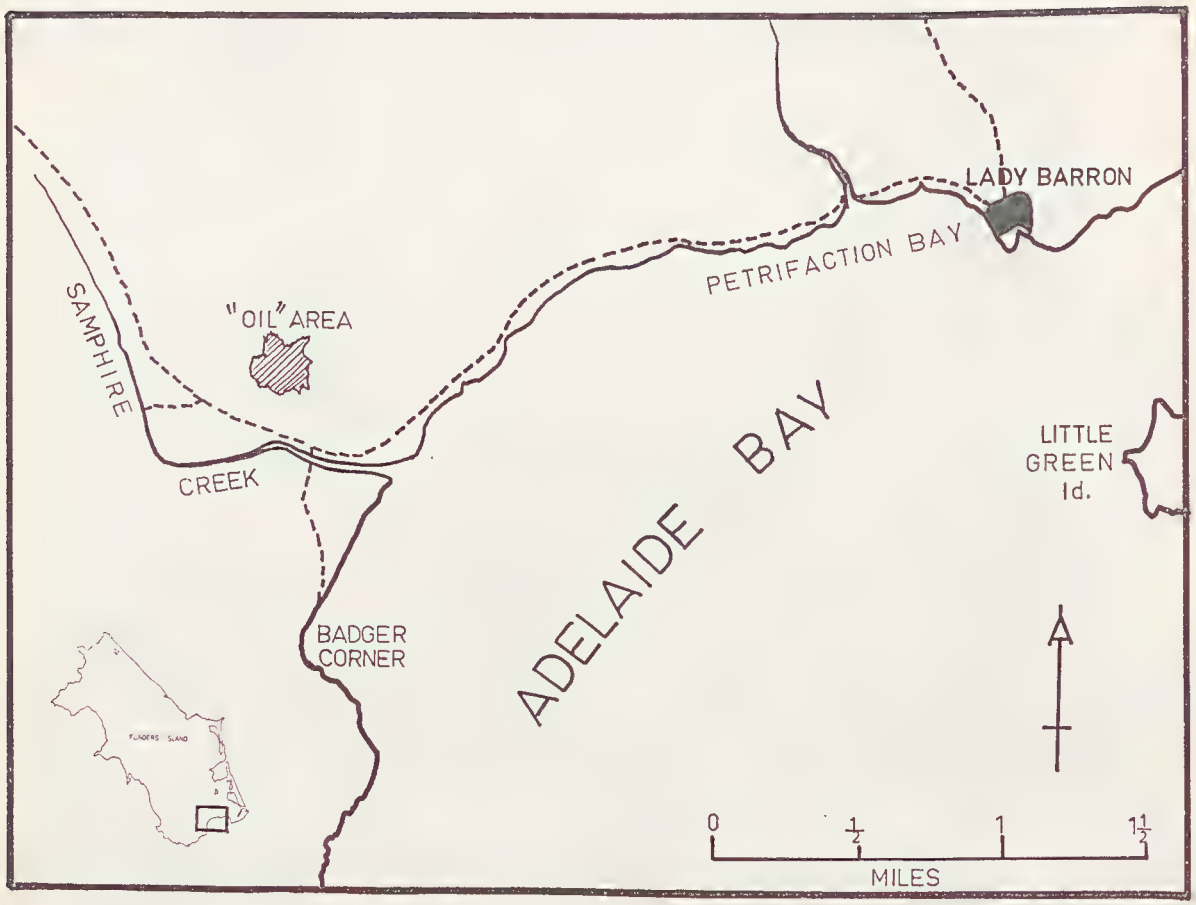
PHYSIOGRAPHY

The particular area is sparsely covered with vegetation and the alleged oil-yielding lagoon lies in a slight depression in the south coastal plain, about 700 yards north of the crossing of Samphire Creek by the road to Badger Corner—(the position is shown on the chart on the following page).

The vegetation, which has been described by Dimmock (1957) can be depicted as low open heath scrub on an acid humus podzol. Ground cover is provided by grasses, sedges, heaths and various reeds, while the dominant flora are teatree and banksia which occur together as dense scrub in patches in an otherwise fairly treeless area, there being no trees much higher than about fifteen feet. It is particularly interesting to note that, although the "petroliferous" material is a semipeat, composed almost entirely of what appears to be organic detritus substantially from Blackboy or Yacca (Xanthorrhaea australis), the lagoon and immediate surrounds are now devoid of this plant. This difference is almost certainly connected with a bygone change in level of the water table, Xanthorrhaea being particularly adverse to wet ground conditions. However, a mile away, on dry ground, stands of Xanthorrhaea are so thick as to allow little else to grow.

Although, at the time of the visit, the countryside was very dry, excavations at the lagoon itself showed brackish water only a few inches below ground level, small areas being quite marshy. It is alleged that, during the winter, the depression is thinly covered with "oily" water over an area of about 40 acres. The soil in the lowest areas showed salt encrustation.

Soil sections showed an upper layer of 1"-3" of recent vegetal remains, followed by varying thicknesses (2"-8") of a brown-black peaty soil, in which were embedded numerous small pieces of very porous charcoal. This char appeared to originate from frond-like vegetation and its presence supported the statements regarding the earlier fires. Below, was a layer of heavy black soil, followed by quartzitic gravel and then clay. By diligent



searching in the scrub, areas were found composed of small knolls (1-2 feet in diameter) of nearly pure organic matter; these had apparently escaped the fires.

Restricted sapropelic decomposition was occurring in the marshy portions of the area as certain spots had an odour of hydrogen sulphide. The writer was told that an inverted can would collect enough gas to burn with a flame as it issued from a small hole in the top. This gas is very probably methane arising from the bacterial decomposition of cellulose. Nevertheless, a combustible gas would certainly lead to further credence of the occurrence of mineral oil. The water was covered with a thin film of resinous organic matter ("oil"), possibly derived from the yacca gum of a past era.

THE "OIL" YIELDING MATERIAL

Laboratory examination of the dried semipeat, and of earlier samples taken in 1934, showed the major portion to consist of a curious dun-coloured matrix of friable corky nature, in which were embedded many charcoal particles and small fibrous remains of other plants. When dry, the substance was extremely hydrophobic and had a specific gravity of only 0.31. The dry material ignited readily and burnt with a smoky flame, the fumes having a strong smell of burnt cork. When the flame was extinguished, the material smouldered away until all the carbon was consumed, leaving a white ash amounting to 7.8% on a dry basis. The slow smouldering of the substance permitted a certain amount of dry distillation to occur ahead of the actual burning area, producing a soft yellow, waxy material. The volatiles had a resinous smell, and in no way resembled those from crude petroleum or from oil shale. The ultimate analysis of the raw organic matter showed (on a d.a.f. basis):

Carbon	64.85%	
Hydrogen	7.58%	
Nitrogen	0.83%	
Sulphur	1.35%	
Oxygen	25.39%	(diff.)

A study of the well-known diagram of Ralston (1915) showed that this material is outside the conventional limits of elaterites, kerogens, peats, lignites and other such material, but is within an area occupied by plant cuticles, resins, exines and certain sapropels (Bajars, 1958).

Microscopic examination of the dissected material revealed an entirely disorganised mass of plant debris devoid of any bedding plane. The substance was made up of highly suberised tissue and cutanised vascular remains, flakes of cuticle, specks and fragments of resins and pollens, bacterial residues and charcoal particles, together with large plant remnants and cells. The whole was in such a fine state of subdivision that, to the naked eye, the material was reasonably homogeneous. True cellulosic remains were not very evident and, presumably, had been removed by bacterial action. With the assistance of the Botany Department of this University, some larger plant fragments were identified as basal portions of the fronds of Xanthorrhaea australis. It is apparent that the plant tissue must have suffered extensive cutinisation which, together with the resins and waxes provided the bacterial-resistant portion of the debris; cuticles are very resistant to such conditions, even over geological periods. Suberisation had occurred to an extent such as to give the whole a friable corky nature, which accounted for the smell of the burning material.

When heated in a modified form of the Gray-King apparatus (Fuel Board, 1940) the dried substance yielded an orange resinous viscous "oil". The assay figures were (% w/w):

	"Oil"	*Liquor*	*Char*	*Gas (diff.)*
Sample 2B4 (1934)	47.2	12.2	35.6	5.0
Sample 3B6 (1965)	39.3	11.6	44.0	5.1

The aqueous liquor was acid, strongly reducing in character and, when made alkaline, evolved an ammoniacal smell. Some of the "oil" no doubt exists as resins (yacca gum) in the raw material as a Soxhlet extraction with isopropanol/hexane showed 11.2% solubles. Ultimate analysis placed the extract in the centre of the resin area of the Ralston diagram and the infra-red spectrum supported this classification.

The pyrolystate "oil" was surprisingly high in tar acids (13%) which were substantially phenolic. Tar bases appeared to be absent.

The distilled acid-and-base-free pyrolysate (neutral portion) was a yellow liquid which darkened on exposure to air. Although somewhat waxy, the high refractive index ($n_D^{25} = 1.5098$) and the infra-red spectrum, showed that long chain carboxylic acids or hydrocarbons were not predominant. The spectrum was characterised by several strong peaks corresponding to carbonyl groups in a carboxylic environment. CH_2 stretch frequencies were present and other notable features were absorption at 748 cm^{-1} (benzene ring deformation and substitution) and peaks at 1270-1230 cm^{-1} corresponding to phenolic esters. There was no reasonable correlation between the spectra of montan wax, ozokerite or crude petroleum and that of the present "waxy oil".

The above data, then, definitely excludes any notion of the deposit, or the "oil", being derived from, or associated with, mineral hydrocarbons or oil shale. On the other hand, the chemical evidence supports the hypothesis that this material represents a curious plant degradation product formed under abnormal conditions; this hypothesis is borne out by the macroscopic and microscopic examinations. The "oil" associated with the maceral is of a resinous nature and is partially derived from natural resins and gums and partially from pyrolytic decomposition of the plant debris. The major chemical components of the semi-solid pyrolysate appear to be substituted phenolic esters, phenols, hydrocarbons of varying chain length, together with a considerable portion of complex chemicals of indeterminate nature. The conditions giving rise to the deposit can be envisaged as an extended period (or periods) of lush growth of characteristic plants, possibly nearly exclusively Xanthorrhaea and grasses, followed by the total death of the stand by a change in environment, probably an alteration in the water table. If Xanthorrhaea were the main contributor to the deposit, there is no doubt that the phenolic constituents of the yacca gum could indeed affect the whole nature of the subsequent microbiological decomposition process.

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ERRATUM—THE GEOLOGY OF THE MT. ELEPHANT-PICCANINNY POINT AREA, TASMANIA

By

R. D. McNeil

(Published in Volume 99 of the Papers and Proceedings.)

On the Geological Map of the Mt. Elephant-Piccaninny Point Area the names "St. Marys Porphyry" and "Adamellite" were inadvertently transposed. The symbol shown for Adamellite is in fact the symbol for St. Marys Porphyry, that shown as for St. Marys Porphyry is in fact that for Adamellite.

D. E. WILKINSON, Government Printer, Tasmania.

PAPERS AND PROCEEDINGS

OF

The Royal Society of Tasmania

Volume 101

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1967.

The Royal Society of Tasmania

Volume 101

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Royal Society of Tasmania

Papers and Proceedings Volume 101

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Royal Society of Tasmania

Annual Report for the Year 1966.

The Council submits to members the following report on the activities for the year 1966.

Two particular items of importance marked the year. The one hundredth volume of the *Papers and Proceedings of the Royal Society of Tasmania* was printed and distributed. The first volume was printed in the year 1849, six years after the Society was formed through the efforts of Sir J. Eardley Eardley-Wilmot, the Lieutenant-Governor of the State at that time. Lack of finance on some occasions, and of suitable material on others, resulted in breaks in the annual publication of the journal but it is to the lasting credit of the Society as a whole that the *Papers and Proceedings* have been continued through the years as an important function of the Society's being. The exchange list is now a large one and through this medium the library receives many useful exchanges. In fact it is true to say that from the point of view of the library, the production of the *Papers and Proceedings* is of the utmost importance.

On a special occasion, at one of the meetings, the Clive Lord Memorial Medal was awarded to Dr. Winifred Curtis, Reader in Botany, University of Tasmania, for her outstanding contributions to botanical knowledge in the State of Tasmania. After receiving the award, Dr. Curtis delivered a special lecture to mark the occasion.

Membership.

The membership of the Society stood at 596 at the end of the year, including three Honorary Life Members.

Professor Arnold Wall of Christchurch, New Zealand, had been a Corresponding member of the Society for 64 years. Although he held the Chair of English at the University of Canterbury for many years, he was a keen botanist and made significant contributions to this branch of science. His death during the year ended a very long association with this Society.

Northern Branch.

The Northern Branch had another successful year and in addition to ordinary meetings, a number of excursions were arranged.

Library.

The total of 600 volumes, books and journals, was added to the Library during the year. Most of the journals were received by the Society in exchange for the *Papers and Proceedings*.

Meetings.

The Annual General meeting was held in March and the elections required under the provision of Rule 7 resulted in Dr. D. Martin becoming a Vice-President in place of Mr. E. C. Gifford, and Mr. M. R. Banks and Dr. J. M. Gilbert being elected to the Council to fill the vacancies left by Mr. J. V. Cook and Mr. G. K. Meldrum who had served their three year term.

During the year Mr. R. A. Both left the State and his place on the Council was filled by the election of Dr. E. R. Guiler, who completed the term of Mr. Both's membership on the Council.

The positions of Honorary Treasurer, Honorary Secretary and Honorary Auditor were filled by the re-election of Mr. G. E. A. Hale, Dr. W. Bryden and Mr. A. M. D. Hewer respectively.

After the business three selected films, obtained through the courtesy of the State Library and Qantas Empire Airways Ltd., were shown to members.

Eight General meetings were held during the year. The speakers and titles of talks were as follows:—

April: Dr. G. L. Kesteven, Assistant Chief, Division of Fisheries and Oceanography, C.S.I.R.O., on "Methods of Fisheries Research—Crayfish and Tuna".

May: Dr. E. R. Guiler, Department of Zoology, University of Tasmania, on "Black Swan Study".

June: Inspector A. K. Jackman, Public Relations Officer, Tasmanian Police Force, on "Development of the Police Administration in Tasmania".

July: Mr. R. J. Solomon, Department of Geography, University of Tasmania, on "Hobart Town Then and Now: Aspects of Urbanisation".

August: Mr. W. Asten, Federal President of the United Nations Association of Australia, on "Australia and the United Nations in Tomorrow's World".

September: Mr. Paul T. Unwin, Management Officer, Forestry Commission, on "Planning the Forests of the Future".

October: Dr. Winifred M. Curtis, Department of Botany, University of Tasmania, received the Clive Lord Memorial Medal, and delivered the Clive Lord Memorial Lecture on "The Endemic Flora of Tasmania".

November: Mr. W. F. Ellis, Director, Queen Victoria Museum and Art Gallery, Launceston, on "The Black War".

Acknowledgements.

The Council is most grateful for the help so generously given by many individuals and organisations, to the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery, the Queen Victoria Museum and Art Gallery, the Press, the Radio, and to the many members and individuals outside the Society who have assisted during the year.

Northern Branch

Annual Report, 1966.

Arising from the Annual General Meeting of the Northern Branch which was held on 25th March, 1966, the Branch Council was composed as follows:—

Chairman—Mr. Justice G. H. Crawford.

Vice-Chairman—Dr. J. C. H. Morris.

Past Chairman—Mr. T. E. Burns.

Hon. Secretary and Treasurer—Mr. W. F. Ellis.

Council Members—Mrs. M. P. Cameron, Mr. J. N. Gee, Mr. T. W. W. Sharpe, Mr. K. E. G. Robinson, Mr. F. L. Sutherland.

By ballot at Council, Mr. Robinson was selected to complete the remaining year of Mr. L. W. P. Reeve's term on the Council. Mr. Justice Crawford and Mr. Ellis represented the Branch on the General Council of the Society and Mr. Ellis also served on the Standing Committee. Mr. Justice Crawford continued his term on the Cradle Mountain-Lake St. Clair National Park Board as nominee of the Northern Branch.

Membership.

The Branch membership on 31st December, 1966 was 241.

Activities.

Ten General Meetings and one Special Meeting were arranged at which the following lectures were given:—

25th February, 1966—"Bushranging in Tasmania" by Mr. G. H. Stancombe.

21st March, 1966—"The Control of human fertility" by Professor H. M. Carey.

22nd April, 1966—"Slavery in Tasmania—convicts, paupers and aborigines" by Mr. K. M. Dallas.

27th May, 1966—"Black Swan studies" by Dr. E. R. Guiler.

24th June, 1966—"History of Police Services in Tasmania" by Inspector A. K. Jackman.

22nd July, 1966—"The Launceston Public Library" by Mr. W. Sutherland.

26th August, 1966—"Harvesting the sea" by Mr. A. M. Olsen.

23 September, 1966—"Economic policy and the Vernon Report" by Professor G. G. Firth.

28th October, 1966—"The Black War in Tasmania" by Mr. W. F. Ellis.

18th November, 1966—"The Townscape in Tasmania" by Mr. R. J. Solomon.

9th December, 1966.—Members' Night—

"Lithographs of old Tasmanian shops" by Dr. C. Craig.

"The Centenary of the old Hagley Church" by Miss N. King.

"If Winter comes—can Spring be far behind" by Miss M. Green.

"The old Glenora schoolhouse" by Mr. E. G. Scott.

"A Bird in the hand" by Mrs. I. J. Mead.

Excursions.

Six excursions were arranged to areas of scientific and historical interest:—

27th February, 1966—Scenes of bushranging around Launceston.

26th June, 1966—Launceston Post Office.

24th July, 1966—Launceston Public Library.

25th September, 1966—Department of Agriculture Research Farm, Cressy.

5th-7th November, 1966.—North-East Tasmania.

27th November, 1966.—Latrobe, East Devonport and Northdown.

Council.

The Council of the Northern Branch met four times during 1966. In addition it was represented at four meetings of the General Council.

Acknowledgements.

The Branch Council records its appreciation of the Launceston City Council for the facilities at the Queen Victoria Museum which have been provided during the year.

Papers and Proceedings of the Royal Society of Tasmania, Volume 101.

THE GEOLOGY OF THE RICHMOND-SORELL AREA

By

C. G. Gatehouse

Bureau of Mineral Resources, Canberra.

(With three text figures.)

ABSTRACT

Permian mudstones and sandstones crop out over much of the Richmond area; Triassic sandstones, shales, and coal measures occur east of Richmond and in the Sorell area. Faulting of Permian and Triassic strata and injection of dolerite, possibly as sheets, broke up the area.

Lakes formed in fault-angle troughs produced by Tertiary faulting; deposits in them occur between Richmond and Sorell. Faults of Jurassic and Tertiary age trending north and west of north control topography and stream direction. The Richmond Graben is Jurassic, pre-dolerite in age: Tertiary movement occurred along earlier lines of weakness.

INTRODUCTION

The area under consideration comprises two ten-thousand yard squares, which have been designated the Richmond and Sorell squares, because these are the largest townships in those squares.

Roads linking Hobart, Richmond, Sorell, Orielton and Brighton give easy access.

The high land levels are covered by an open sclerophyll forest with a low understory of shrubs. The lowlands are, in the main, grasslands which are used for grazing and cultivation. The highlands support sheep, whilst in the vicinity of Richmond, Sorell and Orielton dairy cattle occupy the richer pastures.

Rock exposure, except on the shores of Pittwater and in creeks and rivers, is poor; some difficulty was thus experienced in determining boundary positions of some stratigraphic units. Mapping was carried out by walking the outcrop and plotting rock boundaries on aerial photographs. Together with this several magnetic-variation traverses were made to determine the form of some isolated areas of dolerite north of Richmond.

A basemap was constructed on a scale of 20 chains to one inch using the slotted template method; the geology was plotted onto this from the aerial photographs. Grid references in the text are given in the same manner as used by the Army.

PREVIOUS LITERATURE

Previous notes on various aspects of the geology of the Richmond-Sorell area have been published by Johnston (1888), Nye (1922), Hills *et al.* (1922), Edwards (1939) and Lewis (1946). More recently Moore (1965) has commented on part of the Richmond Square.

ACKNOWLEDGEMENTS

Thanks are due to the staff of the Geology Department, University of Tasmania for their help and encouragement during the fieldwork, compilation of the map and preparation of this paper. Mr. M. R. Banks identified many of the Permian fossils and constructively criticised the manuscript.

PHYSIOGRAPHY

The physiography of the Richmond-Sorell area has been controlled by Tertiary faulting, secondarily by rock distribution.

In the south, east, and north-east of the area the hills are rounded, with an average altitude of about 600 feet and a maximum of 1786 feet at Grass Tree Hill. To the north-west the hills are angular, steep-sided, and frequently fringed by talus slopes. Dolerite caps many of the hills, and the valleys are eroded into softer Triassic sediments.

Tertiary faults, striking approximately north-west and downfaulted to the east, have controlled stream directions. In common with other parts of Tasmania, Tertiary faulting is of the tilted block type. The troughs so produced were, in some cases dammed, thus producing freshwater lakes. Three major physiographic features, the Duck-Hole Creek, the Coal River, and the Orielton Rivulet valleys are all sites of one or more Tertiary lakes. The sea obscures the southern limits of these valleys but the northern and upper limits of the lake sediments indicate a single lake in this area.

Davies (1959) defined the Llanherne and Milford levels just south of the area; his observations can be extrapolated along the shores of Pittwater. In spite of these two levels indicating emergence, the coastline is one of submergence.

In its lower reaches, the Coal River has filled the valley with sediment and formed a delta at the coast.

STRATIGRAPHY

PERMIAN SYSTEM

Malbina Siltstone and Sandstone

This formation is exposed at three points on Belbin Rivulet (230305) and at a locality one mile west southwest of "Strathayr". The rocks of the Malbina Siltstone and Sandstone are poorly exposed at Belbin Creek; about 20 ft. crop out above the dolerite and the top 15 ft. of the formation below the Risdon Sandstone can be observed. The total thickness of the unit here would be about 100 ft.

Lithologically this unit consists of a pale brown, fine-grained matrix containing angular quartzite fragments up to four centimetres in diameter, with occasional larger erratics. Bedding is 12 to 18 inches thick.

Fossils, normally uncommon in this unit, form a coquinite immediately below the Ferntree Group. The observed fauna comprises *Strophalosia*, spiriferids and fenestellids. Banks and Read (1962) give a thickness of 300 feet for this formation in the type area and an Upper Artinskian or Kungurian age. In the Richmond square correlates of Member "E" of the type area are present; the uppermost part of member "D" may also be present.

FERNTREE GROUP

Risdon Sandstone

The Risdon Sandstone is the basal unit of the Ferntree Group, it conformably overlies Malbina Siltstone and Sandstone and is overlain by Ferntree Mudstone. The unit is a well-sorted, soft, yellow-brown sandstone containing subangular quartzite fragments, muscovite mica, graphite and occasional small pebbles. The thickness varies from 15 to 20 ft. Typically the Risdon Sandstone forms a narrow bench and small cliff more or less following the contours. Two small faults with throws of 30 feet or so have caused this unit to recur in three outcrops in Belbin Rivulet at (235350).

Ferntree Mudstone

Outcrops of Ferntree Mudstone occur over large areas of the Richmond square. At (248305) Risdon Sandstone conformably underlies this unit which is itself overlain by Cygnet Coal Measures at (227328). It is a buff, very fine-grained, compact mudstone containing a few isolated angular pebbles of quartzite, slate and granite. At (325303) on Shark Point several bands of conglomerate about one foot thick are exposed and patches of angular boulders also occur there.

Fossils are not common in the Ferntree Mudstone. However, *Stutchburia costata* (Morris), *Cleobis grandis* Dana, *Pachydomus* and *Terrakea* cf. *fragile* may be found 100 to 150 feet below the Triassic at (342323). Worm tracks, fossil wood, *Stenopora* and spiriferids are part of the fauna at Shark Point.

Cygnet Coal Measures

Only one outcrop of Cygnet Coal Measure is known in the area. It is exposed in a small roadside ditch at (228328). A maximum of 4 feet of laminated carbonaceous siltstone is exposed here.

TRIASSIC SYSTEM

Ross Sandstone

The base of the Ross Sandstone is marked by a pink, pebbly sandstone, the matrix of which is a fine-grained sand of quartz, feldspar and muscovite, carrying pebbles up to 40 mm. in diameter. Sorting is poor and cement almost absent in this unit. This basal bed may be observed at (228328) and (285370).

The bulk of the Ross Sandstone comprises sandstone and shale. The formation exceeds 400 feet in thickness. Because the shale weathers more rapidly than the sandstone, outcrops of it are obscured by surface rubble. The sandstones are strongly cross-bedded, showing that bottom currents were from the west, which is consistent with current directions at other localities. Occasional slump structures of the type recorded by McDougall (1959, p. 70), are found in the cliffs at Midway Point. "Clay-pellet" conglomerates are frequent at Midway Point and on Butchers Hill. The pellets comprise oval discs of pink to white mudstone, apparently with a preferred orientation, set in a fine-grained sandstone matrix.

Knocklofty Sandstone and Shale.

Those rocks which are correlated with Knocklofty Sandstone and Shale, outcrop at (363223) in Duck Hole Creek on the Richmond square. Strongly chloritic sandstones, micaceous shales containing plant fossils, clean white sandstones, and clays, occur in the creek bed. One of the clay beds contains numerous worm tubes 5-10 mm. long and 3-5 mm. in diameter filled with the overlying sediment. Outcrops also interpreted as this unit occur at Sheoak Hill and in the roadway at (379825). Quaternary gravels on the western edge of Sorell square apparently conceal the Knocklofty Sandstone and Shale, as several creeks in the area have cut through the veneer of gravel into a sequence of sandstone and shale similar to this unit.

Lithic Arenites

Overlying the Knocklofty Formation is the so-called "Feldspathic Sandstone". Only one exposure, 200 yards downstream from the weir on the Coal River at Richmond, is known. A bore sunk by the Department of Mines in 1922 at the above locality revealed the presence of at least 500 feet of clays, sands, coal, and shales, belonging to this formation. A cliff face in this locality exposes coal seams a foot or more in thickness.

Tertiary System

Tertiary sediments occur along the southern boundary of both Richmond and Sorell squares, with deposits extending north of Richmond in the valleys. Pale grey clays and sands are exposed in cliffs along the Coal River under the Catholic Church at Richmond, on the coast of Pittwater near Penna, and 1½ miles south-east of Gunns Sugar Loaf.

Angiosperm leaf impressions were found east of Shark Point and 1½ miles south-east of Sheoak Hill close to the Richmond-Sorell road.

The clay deposits, as exposed near Shark Point and Penna are at least 15 feet thick. When wet these clays, particularly the white and pale grey strata, are plastic. The clay was apparently derived from the dolerite by weathering in the catchment area of streams feeding into the lakes.

IGNEOUS ROCKS

Jurassic System

In the Richmond-Sorell area dolerite crops out as slightly transgressive sheets except at Shark Point where two small dykes occur. In general the

dolerite is a fine to medium-grained rock of uniform texture and of grey-blue colour when fresh. In thick sheets, such as north of Grass Tree Hill and north of Sorell, the rock is distinctly pegmatitic away from the edges of the mass. Extremely fine-grained dolerite occurs at contacts with country rock and the sedimentary rocks are hornfelsed. The intensity and extent of thermal metamorphism is small and McDougall (1959, p. 64) has suggested that this may be due to a lack of fluids and low thermal conductivity of the country rock.

An outcrop of fine-grained dolerite in a small excavation in basal Triassic sandstone, at the base of Butchers Hill near the northern end, may be an offshoot dyke from the main intrusion. As the Coal River Fault is several hundred yards to the east, this outcrop is not laterally connected with the dolerite sheet south-east of Richmond.

Tertiary System

Basalt flows occurred at Sorell, Gunns Sugar Loaf, Richmond, Penna, Midway Point and Orielton. Phenocrysts of olivine indicate an olivine saturated magma, as is common in the lower reaches of the Derwent Valley. Opaline silica, chalcedony, and zeolitic amygdules are frequently associated with the basalt.

Near the summit of Gunns Sugar Loaf is an outcrop of basalt about 20 yards across and completely surrounded by dolerite; it contains small xenoliths of dolerite and grey clay-rich fragments of Triassic (?) sediments. It is suggested that the basalt is a plug as no Triassic rocks occur above the outcrop but they do crop out some 400 feet down the hill.

South of Sorell in a river bank pahoe-hoe lava indicates a basalt flow; large polygonal cooling columns 15 feet high and 10 feet across were formed from one flow of basalt. Occurrences of basalt in the Orielton-Penna-Sorell valley indicate that the valley floor was flooded with basalt. Several lava flows crop out below the Catholic church at Richmond where they overlie lake sediments and are overlain by gravels. A chalcedonic structure reminiscent of a tree-trunk penetrates three feet into the base of the basalt there.

Outcrops of basalt north and west of Orielton are about 200 feet above sea-level thus indicating a source or sources topographically above this, presumably north of the Sorell Square.

STRUCTURE

Faulting

Faults of Jurassic and Tertiary age occur in the Richmond-Sorell area (Fig. 1). Some of the Jurassic faults also exhibit Tertiary movement.

Jurassic Faults

The Bagdad Fault of McDougall (1959) continues, as suggested by him, along the Back Tea Tree Valley. At a point half a mile south of Bourbon Homestead (220377) the fault becomes manifest and continues in a south-easterly direction parallel to the Back Tea Tree Road. At (240348) the fault is obscured by a dolerite mass, the easterly contact of which is steep and may be the fault plane. Hastie (unpublished Honours thesis 1961) has found evidence for the continuation of this fault south of the Richmond square into the Lindisfarne square. Near Bourbon this fault has a throw of approximately 700 feet. The fault is pre-dolerite or contemporaneous with the dolerite.

The Coal River Valley is the topographic expression of a pair of parallel faults of Jurassic age. The graben was initiated prior to the injection of dolerite when the "Feldspathic" Sandstone was faulted down to the lower levels of the Ross Sandstone. A single sheet of dolerite was injected. Subsequent movement along the western fault, here named the Coal River Fault, occurred in Tertiary times and gave rise to Butchers Hill as it is now known. Jurassic movement along the western fault was of the order of 1200-1300 feet, and Tertiary movement 300-400 feet. The eastern limit of the graben, here called the Richmond Graben, is a fault whose position and throw are not accurately known owing to a core of dolerite and scant sediments. The graben does not appear to be more than one mile wide at Richmond and is less than this to the south.

The Richmond Fault (Lewis 1946) does not appear to be as long as he indicated; from the dolerite at (238342) it extends in a south-westerly direction up into the Triassic sediments. Because this fault does not continue either into or past the dolerite it must be regarded as pre-dolerite. Two deep, steep-sided gullies meet at (230337); the southern branch is cut along a fault of only a few feet throw, whilst the northern branch appears to be eroded along an extension of the Richmond Fault. If this latter gully is along a fault the throw is such as not to affect the surface geology noticeably.

Two faults near Dulcot and several small faults between Shark Point and Penna are also of Jurassic age.

Tertiary Faults

A fault in the Duck Hole Creek Valley, here named the Cold Blow Fault, is of Tertiary age with an estimated throw down to the east of more than 1000 feet. Its estimated position is 300 yards west of the southern end of Butchers Hill and running parallel to the western edge of it. From its topographic expression the Cold Blow Fault continues north of the Richmond square.

The Coal River Fault has already been mentioned as having Tertiary movement.

In the Grass Tree Valley a system of two subparallel faults—the Shellstone Fault to the west, the Strathayr Fault (new name) to the east—form the limits of the Grass Tree Valley Graben. Throws of the faults of this graben are more than 450 feet and more than 690 feet respectively. The East Risdon (south of Richmond square)-Richmond road cuts the Shellstone Fault at four points, so that Permian and Triassic sediments alternate along the road cuttings.

fig. 1a. JURASSIC FAULT SYSTEM

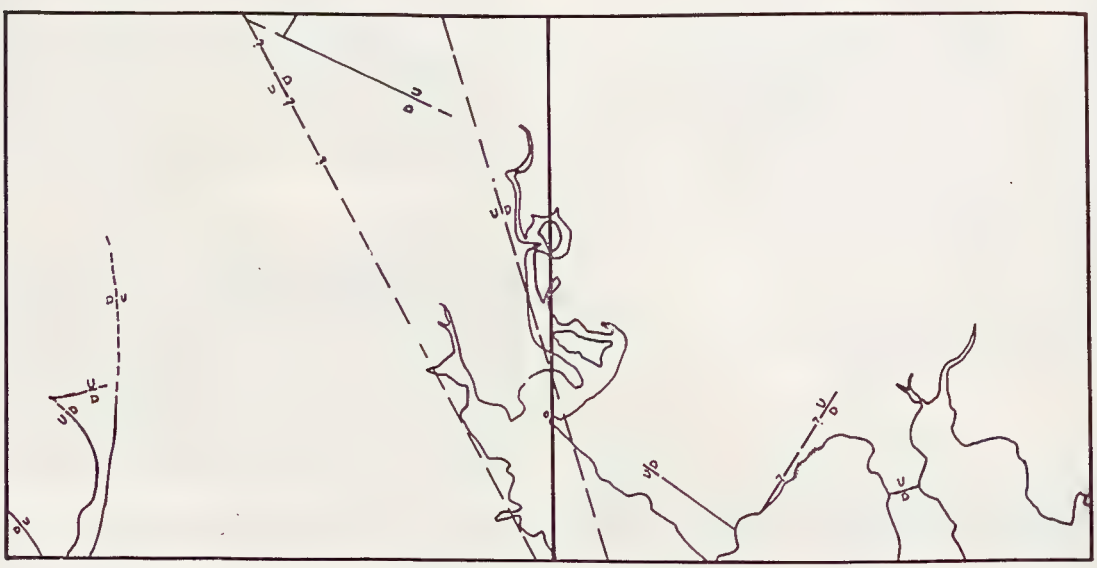

fig. 1b TERTIARY FAULT SYSTEM

Structure of the Dolerite

Jurassic dolerite, in this area, has transgressively intruded Permian and Triassic sediments and because of its greater resistance prominent features of present-day topography are invariably capped by it. Two small dykes outcrop at Shark Point, but elsewhere the dolerite occurs as a sill. However, where the top and bottom contacts of a sill have been observed both may be flat lying or one may be steeply inclined. Structural interpretations of the dolerite have been presented by Carey (1958, p. 134).

Extensive sills of dolerite occur at Grass Tree Hill, Mt. Lord, Sheoak Hill and north of Sorell.

The intrusion between (236350) and the southern boundary of Richmond square has a steep eastern contact with a flat-dipping contact on the western or uppermost side.

Two superimposed dolerite sills separated by about 30 feet of sediment occur one mile north-west of Richmond. The upper contact of the lower sill is chilled and the overlying sediments baked, and the higher intrusion has its lower contact chilled. Although a small fault cuts across the southern end of the outcrop there is no evidence for a fault between the outcrops of dolerite.

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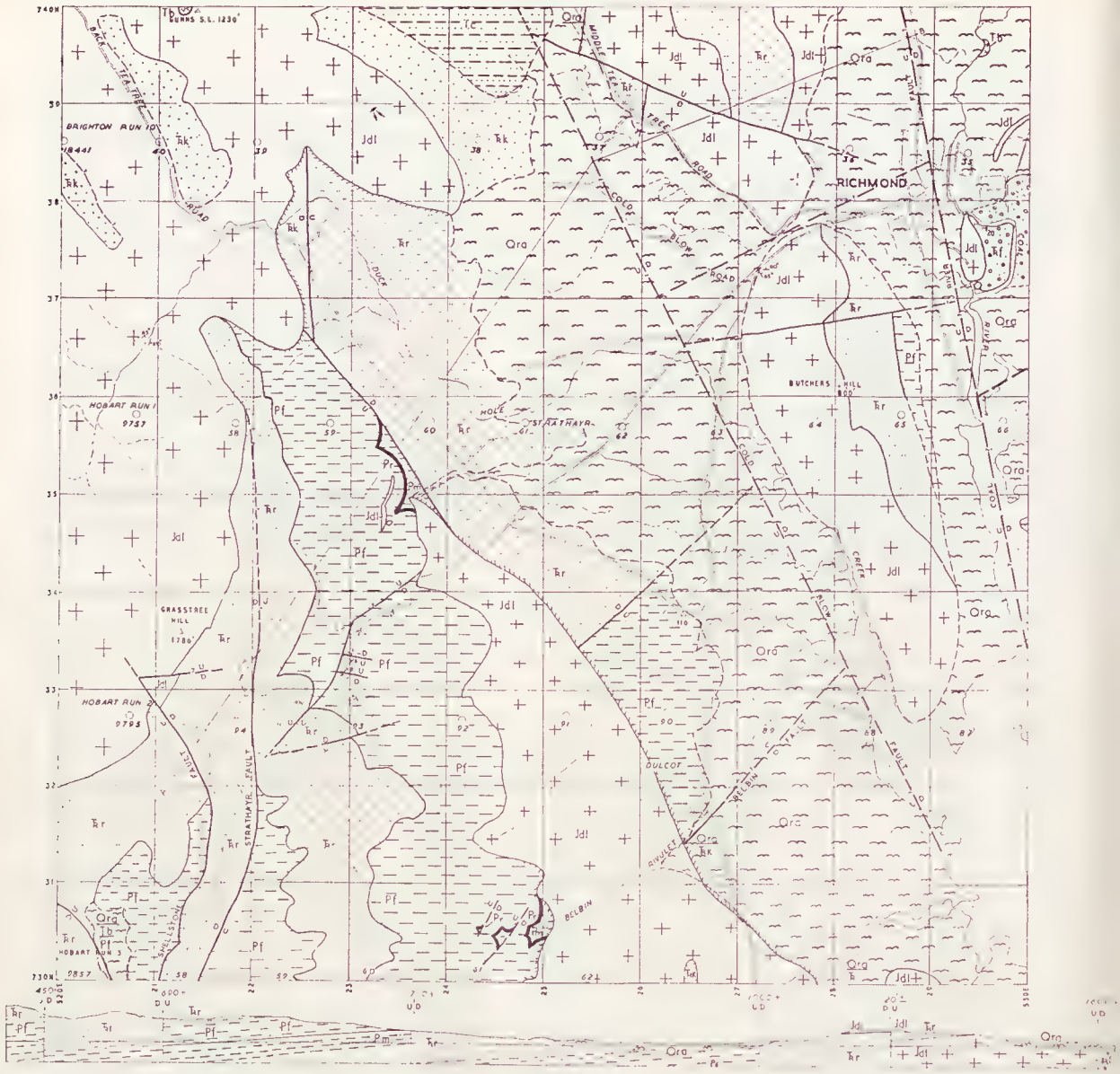
GEOLOGY OF TASMANIA

ONE INCH SERIES—UNIVERSITY OF TASMANIA, GEOLOGY DEPARTMENT

RICHMOND

5273



FAULT WITH DOWNTHROWN SIDE INDICATED
FAULT CONCEALED
FAULT INFERRED
FORMATION BOUNDARY
FORMATION BOUNDARY POSITION APPROXIMATE

Dolerite Boundaries
CONCORDANT BOUNDARY
DISCORDANT INTRUSIVE BOUNDARIES

VERTICAL JOINTS
STRIKE AND DIP OF JOINTS
STRIKE AND DIP OF STRATA
ROAD
VEHICULAR TRACK

Quaternary System
RECENT SERIES
Qra ALLUVIUM
Tertiary System
Tc CLAYS AND SANDS
Triassic System
Pf FELDSPATHIC SANDSTONE
Tk KNOCKLOFTY FORMATION
Tr ROSS SANDSTONE
Permian System
Pf FERNTREE MUDSTONE
Pp RISDON SANDSTONE
Pm MALBINA SILTSTONE AND SANDSTONE
IGNEOUS ROCKS
Tertiary System
Tb BASALT
Jurassic System
Jdl DOLERITE

LEGEND

Compilation from Aerial Photographs
Trigonometric Station Control by courtesy of the Department of Lands and Surveys, Hobart, and the Australian Army Survey Service.
Origin of co-ordinates 400,000 yds West and 1,000,000 yds. South of True Origin of Zone 7 of the International Grid

KEY MAP SHOWING MAGNETIC DECLINATIONS 1957
SECULAR VARIATION 7' PER ANNUM

MAPPED AND COMPILED BY C.G.GATEHOUSE 1960

SCALE
0 1 2 3 4 5 MILES
0 5,000 10,000 FEET

FIG. 2

GEOLOGY OF TASMANIA
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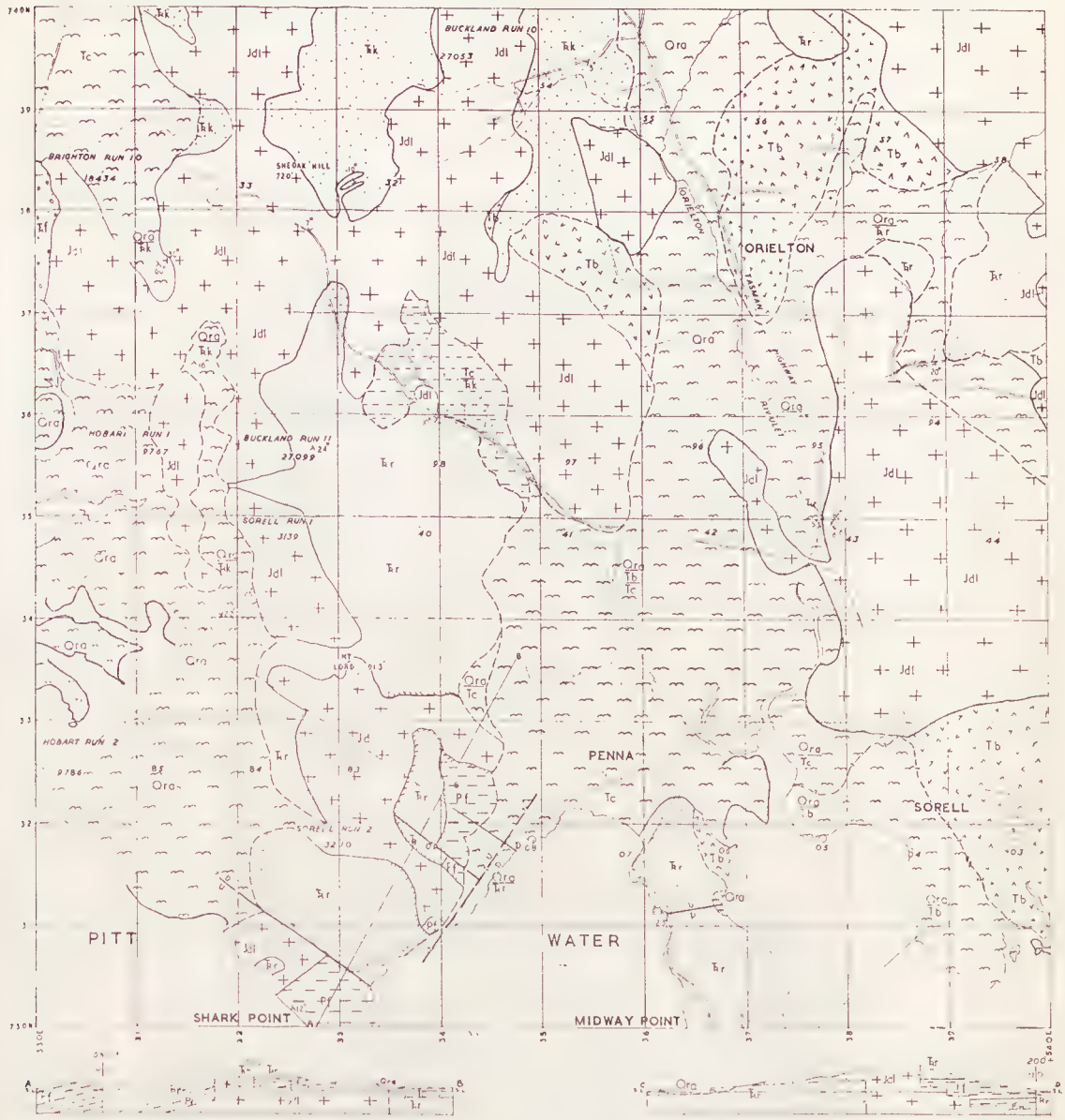
SORELL

5373



LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED
- FAULT CONCEALED
- FAULT INFERRED
- FORMATION BOUNDARY
- FORMATION BOUNDARY POSITION APPROXIMATE

Dolerite Boundaries
- CONCORDANT BOUNDARY
- DISCORDANT INTRUSIVE BOUNDARIES

- VERTICAL JOINTS
- STRIKE AND DIP OF JOINTS
- STRIKE AND DIP OF STRATA
- ROAD
- VEHICULAR TRACK
- FOSSIL LOCALITIES

Quaternary System
RECENT SERIES
- Qra — ALLUVIUM

Tertiary System
- Tc — CLAYS AND SANDS

Triassic System
- Tf — FELDSPATHIC SANDSTONE
- Tk — KNOCKLOFTY FORMATION
- Tr — ROSS SANDSTONE

Permian System
- Pf — FERNTREE MUDSTONE

IGNEOUS ROCKS
Tertiary System
- Tb — BASALT

Jurassic System
- Jdl — DOLERITE

Compilation from Aerial Photographs Trigonometric Station Control by courtesy of the Department of Lands and Surveys, Hobart, and the Australian Army Survey Service. Origin of co-ordinates 400,000 yds West and 1,800,000 yds. South of True Origin of Zone 7 of the International Grid.

KEY MAP SHOWING MAGNETIC DECLINATIONS 1957 SECULAR VARIATION 7' PER ANNUM

MAPPED AND COMPILED BY C.G.GATEHOUSE 1960

SCALE
0 1 2 3 4 2 MILES
0 1000 10,000 FEET

FIG. 3

A NEW ANALYSIS OF DUNDASITE FROM TASMANIA

By

R. J. Ford.

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Dundasite was first described by W. F. Petterd in 1893, and an analysis of Tasmanian material was published in 1910. This analysis shows Fe_2O_3 as a large impurity, with high Al_2O_3 due to probable admixture of gibbsite which is an associated mineral at Dundas. Analyses of relatively uncontaminated material from elsewhere have been presented in the literature (Prior 1906, Palache *et al.* 1951, Beaumont *et* Guillemin 1960) with Beaumont and Guillemin deriving a formula for material from Sardinia of $Pb_2\ Al_2\ (CO_3)_4\ (OH)_8\ 3H_2O$ rather than $Pb\ Al\ (CO_3)_2\ (OH)_4\ 2H_2O$ as suggested by Prior. The analysis was performed by the Australian Mineral Development Laboratories on handpicked material taken from a specimen of dundasite (No. 14134) presented to the University of Tasmania with a collection of crocoite from Dundas.

It agrees well with the proposed formula.

	Dundasite	$Pb_2\ Al_2\ (CO_3)_4\ (OH)_8\ 3H_2O$
PbO	46.60	46.87
Al_2O_3	21.50	21.41
Fe_2O_3	00.02	....
CO_2	18.10	18.48
H_2O+	13.90	13.24
H_2O-	00.08	....
	100.20	100.00

Analyst: C. R. Edmond.

The greatest differences occur between H_2O^+ and CO_2. As these are complementary it is probable that some $(OH)^-$ replaces $(CO_3)^{2-}$ in the structure.

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A RE-APPRAISAL OF JOHNSTONOTITE

By

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(With one plate and one text figure.)

ABSTRACT

Johnstonotite is a mixture of spessartite and grossularite.

INTRODUCTION

In 1899 McLeod and White described a manganiferous garnet from Port Cygnet. This was considered to be a new species and named johnstonotite. The locality was not described accurately, as a result of which A. B. Edwards (1947) indicated an incorrect site for the mineral. Johnstonotite has now been found to occur as phenocrysts in a dyke which outcrops on the western shore of Port Cygnet approximately 200 yards north of the site of the old Lymington deep water jetty (Fig. 1). This was recognised as a result of the discovery of the type specimen of johnstonotite in the collection of the Tasmanian Museum (Spec. No. X1435), by Mr. R. Both. The present investigation stems from a general investigation of Tasmanian minerals by modern methods together with the obvious incompatability of the original analysis with that required for a garnet.

METHODS OF INVESTIGATION

A chemical analysis was performed by the Tasmanian Department of Mines and X-ray data have been obtained from a Philips diffractometer calibrated with powdered silicon, using a 1° divergence slit, 0.1° receiving slit, 1° scatter slit and CuKα radiation filtered with nickel. A xenon proportional counter with pulse height analyser was used as a detector. Larger slits were used for the back reflection region but intensities were recalculated for the smaller slit system.

ANALYTICAL RESULTS

	New Analysis	Original Analysis
SiO_2	36.60	36.87
Al_2O_3	20.50	7.28
Fe_2O_3	0.70	
FeO	2.70	17.12
MnO	26.00	13.68
TiO_2	0.34	....
P_2O_5	0.14	...
CaO	13.10	11.98
MgO	0.00	12.49
Ig. Loss	n.d.	00.29
	100.08 Tas. Mines Dept. 1966	99.71McLeod and White 1899

Formula on the basis of 96 Oxygen atoms per unit cell:

$$\left(Mn^{2+}_{13.496}Ca_{9.036}Fe^{2+}_{1.468}\right)\quad\left(Al_{15.116}Mn^{3+}_{0.421}Fe^{3+}_{0.344}Ti_{0.156}\right)$$

$$\left(Si_{23.516}Al_{0.408}P_{0.076}\right)\ O_{96.000}$$

This formula corresponds with the following molecular percentages: spessartite 53.30, grossular 35.50, almandine 6.12, blythite 2.65, and andradite 2.43. Clearly andradite is not a dominant molecule, as implied in the Chemical Index of Minerals (Hey, 1950). The most interesting feature of the analysis is the apparent excess of manganese oxide in the divalent position thus indicating the possibility of the presence of Mn^{3+} in the structure.

DIFFRACTION RESULTS

Line No.	I	d(obs.)	d(calc.)	hkl
1	4	4.770	4.773	211
2	4	3.120	3.124	321
3	41	2.923	2.923	400
4	100	2.613	2.614	420
5	5	2.493	2.492	332
6	18	2.386	2.386	422
7	12	2.293	2.293	431
8	14	2.134	2.134	521
9	3	2.065	2.067	440
10	19	1.896	1.896	532
11	12	1.687	1.687	444
12	22	1.621	1.621	640
13	25	1.562	1.562	642
14	7	1.460	1.461	800
15	5	1.307	1.307	840
16	8	1.275	1.275	842
17	4	1.246	1.246	664
18	6	1.085	1.085	10.40
19	4	1.067	1.067	10.42
20	3	1.033	1.033	880
21	<1	0.9743	0.9742	12, 0.0, 884
22	<1	0.9609	0.9609	12.2.0
23	2	0.9482	0.9482	12.2.2,10.6.4
24	<1	0.9071	0.9073	9.9.2
25	<1	0.8767	0.8762	9.9.4
26	<1	0.8713	0.8713	12.6.0,10.8.4.
27	<1	0.8436	0.8436	888

Unit cell edge = 11.690 A.U. Second moment deviation = ± 0.005

Density (calc) = 4.026 gm/cc.

Density (obs) = 3.910 gm/cc.
Refractive index = 1.779 ± 0.001 23°C
Na light.

The experimental results are consistent with the determinative table of Winchell as presented by Deer, Howie and Zussman (1962).

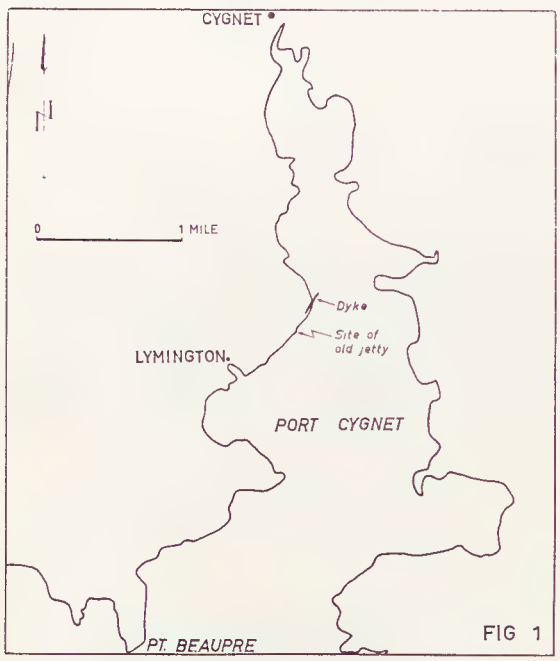

FIG 1

PETROLOGY

Macroscopically, johnstonotite occurs as round reddish-brown phenocrysts varying from 0.5 mm. to 10 mm. in diameter, in a dense fine-grained grey dyke about 50 cm. wide dipping steeply west and striking 015° E magnetic which has caused baking and hornfelsing of the intruded Permian rocks. The dyke has a chilled margin. Often associated with the garnet are crystals of pyrite, up to 5 mm. in diameter. Small crystals of galena, arsenopyrite, and possibly sphalerite are also occasionally visible in the rock. Aggregates of epidote, sometimes comparable in size with those of the garnet also occur.

Microscopically the rock consists of a fine-grained groundmass of lath-shaped simply twinned crystals of sanidine approximately 0.05 mm. x 0.005 mm. showing a characteristic flow structure with occasional porphyritic euhedral crystals of feldspar, predominantly sanidine, having a grainsize of about 2 mm. x 0.5 mm. The groundmass also contains flecks of a greenish-brown weakly pleochroic micaceous mineral. The phenocrysts of garnet have a high relief, are weakly anisotropic, show strong zoning and twinning, and have cracks in which prehnite and epidote have crystallized at a late stage of crystallization (rather than by reaction with the garnet because they do not have the properties of manganiferous varieties). Epidote appears near the rim of the garnet and occasionally in the groundmass. The garnet appears zoned due to the presence of small flakes of mica and epidote which have apparently crystallized in cracks formed at an earlier stage of the growth of the host (Plate I). The texture of the rock suggests crystallization of the garnets as the first mineral at a high temperature, these then acting as centres of crystallization for later formed feldspars and epidote which appear to have grown off the garnet thus giving the appearance of a white rim to the mineral (Plate I). In thin section the rock is best described as a garnet-sanidine porphyry.

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance of the Director and Mr. I. B. Jennings of the Tasmanian Department of Mines who arranged for the analysis of the mineral, Mr. R. Both whose discovery of the type specimen made the present investigation possible, and Dr. A. Spry for comments on the petrology.

CONCLUSIONS

Johnstonotite is not a valid species and should therefore be removed from the mineralogical record. It is a spessartite garnet containing a proportion of grossularite plus accessory molecules.

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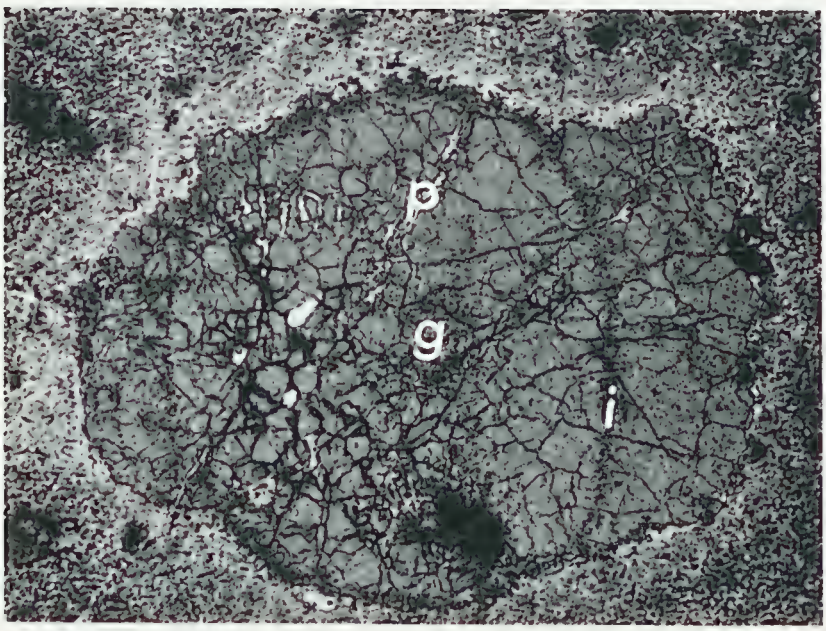

Plate I.—Garnet phenocryst (g) showing rim of feldspar crystals (f), inclusions (i), and prehnite (p). x 7.

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EXAMPLES OF INTRUSIVE ACID DYKES IN EASTERN TASMANIA[1]

by

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(With six text figures.)

ABSTRACT

Observations of the relationship between linear or planar features on either side of dykes usually form the basis of a field determination of their mode of emplacement, although it is known that sections oblique to planar features may lead to conflicting results. In Eastern Tasmania only rarely are examples encountered where dyke wall-rock units are of use. However, dyke wall irregularities are common and a comparison of opposite walls have shown the dykes to be intrusive. Disproportionate offsets of corresponding wall irregularities due to connecting cross-dykes are general, which results in intrusive bodies resembling those of a replacement origin.

INTRODUCTION

In considering the mode of emplacement of dykes Goodspeed (1940) recognised those which dilated the host rock and others which resulted from replacement. The most important criterion noted by which the origin of a dyke may be determined is the geometrical relationship between pre-existing wall-rock linear or planar features on either side of a dyke. Offsets of such features proportional to the width of a dyke and the angle of intersection demonstrate a dilational emplacement, whereas a replacement origin is indicated when units in the wall-rock may be extrapolated across the dyke without offset (fig. 1), or, as stated by Goodspeed (p. 194), with disproportionate offset. King (1948), however, pointed out that where material is intruded along a network of fractures, offset of intersected features disproportionate to the width of the dyke may occur, although he favoured a replacement origin for examples displaying such characteristics (his figs. 4a, 10c). In an evaluation of the criteria for the forcible intrusion of magma, Noble (1952) considered that, not only is it necessary to have a knowledge of the features in all three dimensions, since planes of reference oblique to planar surfaces intersected by a dyke may give apparent displacement either greater or less than the real displacement, but that stoping or assimilation of wall-rocks and granitisation may operate concurrently with forcible intrusion leading to conflicting evidence. Another limitation on the use of offsets was shown by Noble where forcibly intrusive dykes plastically deformed the wall-rocks, which resulted in the lateral displacement of pre-existing features being confined to the zone of plastic deformation, beyond which the features maintained their undeformed position.

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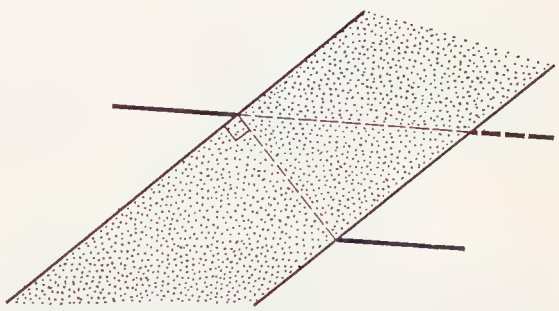

Fig. 1.—Distinctive wall-rock feature (thick line) offset by dilation dyke (stippled). With a replacement dyke position of feature in right-hand wall shown by broken thick line.

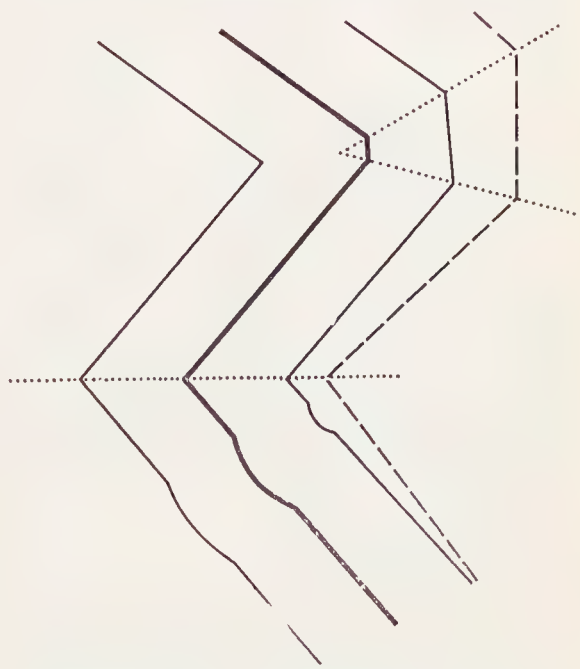

Fig. 2.—Dyke outlined by thin lines resulting from uniform replacement initiated in surface of trace represented by thick line. Note irregularities bounded by diverging angle-bisectors (dotted lines) are enlarged in replacement front. Broken line indicates right-hand wall of dyke of variable thickness.

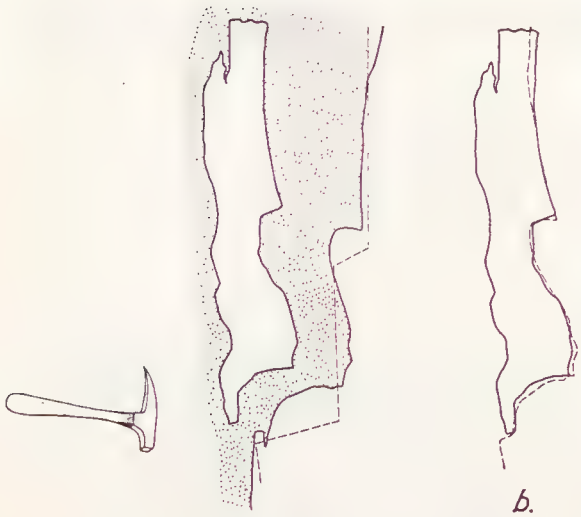

FIG. 3.

a. Tracing of photograph of red micro-adamellite (stippled), with walls vertical to reference plane in grey adamellite at Bluestone Bay. Irregularities correspond at right angles to walls. Broken line is trace of calculated right-hand wall if dyke is of replacement origin, and is quite unlike the actual trace.

b. Right-hand wall (broken line) superimposed on opposite wall indicates close fit demonstrating red micro-adamellite of intrusive origin.

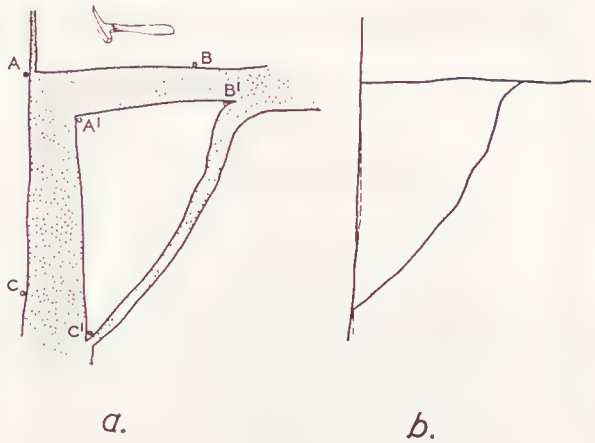

FIG. 4.

a. Tracing of a photograph of muscovite granite (stippled), with walls vertical to reference plane, in porphyritic biotite granodiorite at St. Helens Head. Note offset of points AA', BB' and CC'.

b. Remarkable fit of fragments of porphyritic biotite granodiorite can only be attained if muscovite granite is of intrusive origin. Broken line indicates overlap.

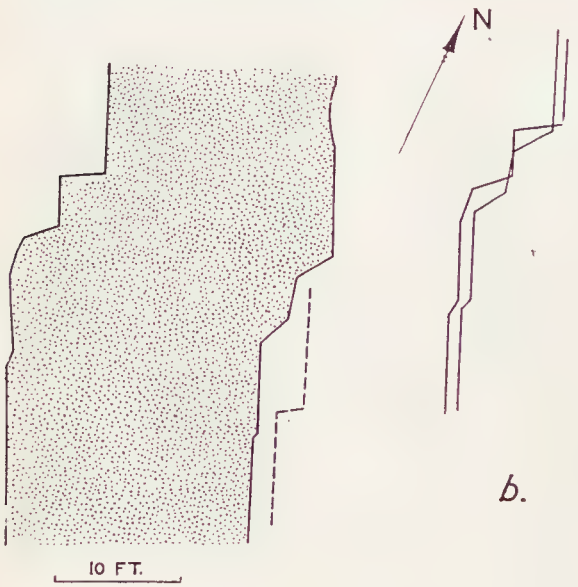

FIG. 5.

a. Mapped example of a cluster of irregularities at a locality along the length of a vertical dyke of quartz-feldspar porphyry (stippled) in red adamellite on the Coles Bay foreshore. Broken line is trace of calculated right-hand wall of dyke of replacement origin, which is quite unlike actual trace.

b. Close fit of margins indicate dilational nature of emplacement of quartz-feldspar porphyry with concomitant lateral displacement of some 7 feet.

FIG. 6.—Tracing of photograph (bottom nearest camera) of an approximately vertical dyke of biotite granodiorite with diffuse margins against hornfelsed sedimentary rocks at Piccaninny Point. Foliation of dyke material, indicated by broken lines, in direction of like irregularities of opposite walls, the similarity of which only accounted for by a dilational mode of emplacement.

In the surveying of granitic rocks in areas of Eastern Tasmania, numerous outcrops of dykes have been found but only occasionally have the dykes investigated been observed to intersect pre-existing features of the host rock, and only rarely have rock exposures been discovered where sufficient evidence is available not to lead to conflicting conclusions. However, dyke wall irregularities are fairly common and a comparison of such features between the walls of dykes proved profitable even in examples where the nature of the surfaces in all three dimensions was not evident.

MATCHING IRREGULAR DYKE WALLS AS A A GUIDE TO ORIGIN

Although it is obvious that marked wall irregularities can match perfectly across only a dilational dyke it is instructive to consider how good a match may develop by replacement. It appears that the most favourable conditions under which a replacement dyke may develop closely matching walls are where irregularities are inherited from a pre-existing surface whom which a replacement front proceeded. Figure 2 illustrates the form of a replacement dyke that may develop from an irregular initial surface, and the diminution of irregularities of the original surface in the replacement front where bisectors of the angles in the irregularities converge. It is evident in figure 2 that the irregularities that may develop in a replacement dyke wall may be determined from the observed trace of the opposite wall providing the dyke thickness is known, although it may vary along its length. It may also be noted that replacement dykes cannot have perfectly matching irregular walls.

At Bluestone Bay on the east coast of the Freycinet Peninsula red micro-adamellite is emplaced in grey adamellite (Groves, in press). Figure 3 is of one of a number of examples at this locality where the irregularities in opposite vertical walls correspond at right angles to the length of the micro-adamellite bodies, and where the close fit of the walls clearly shows that the dyke material intruded the coarser grained grey adamellite.

Displacement of wall irregularities at right angles to the length of dykes are not common in Eastern Tasmania because of the presence of connecting cross-intrusions, as is demonstrated in the example from St. Helens Head in figure 4. However, on a larger scale lateral offsets may be even greater than the dimensions of the outcrop exposed. This has been encountered at Coles Bay on the western shore of Freycinet Peninsula where three NNW trending dykes of quartz-feldspar porphyry occur within red adamellite. The eastern dyke exhibits corresponding wall irregularities displaced at right angles to the length of the intruding body, whereas the middle dilation dyke (fig. 5) shows a lateral displacement of corresponding wall irregularities of some seven feet. The characteristics of the walls of the western dyke at Coles Bay, some 300 yards from the eastern dyke, cannot be matched along a exposed length of some 200 feet. Such results, however, are to be expected in this region where connecting east trending cross-dykes are known.

Finally, it should be noted that lateral displacements of irregular walls by the intrusion of material along a network of fractures may result in dykes which at first sight may appear to be of replacement origin. At Piccaninny Point (fig. 6) dykes of foliated biotite granodiorite have very variable widths, which culminate in pinches and swells, and diffuse boundaries against hornfelsed sandstones and mudstones. Such characteristics are generally believed to be those of a replacement dyke. However, the foliation of the dyke material is actually in the direction linking similar irregularities in opposite walls, which show a correspondence that although it is readily accounted for by a dilation mechanism it could not be explained if the dyke was attributed to replacement.

CONCLUSIONS

To those Survey workers engaged in studies of igneous complexes and gneissic terranes, observations of dilational and non-dilational characteristics of the rock-types are essential in order to determine their origin, all the more so since the necessary microscope examination of the rocks encountered often lags well behind mapping. Goodspeed and King introduced to many the significance of offsets, or lack of offsets, of wall rock units by veins and dykes, but neither considered the use of dyke wall irregularities in determining the nature of emplacement. Irregularities of the walls of dykes examined in Eastern Tasmania have proved not only more common than intersected wall-rock units, but have given a more conclusive guide to the origin of the dykes. Matching irregular dyke walls, even when only approximate, can only result from dilation, since even where replacement behaves in the most ideal way dyke walls must differ unless they are perfectly planar.

Goodspeed, King and Noble considered determination of offsets of wall features of prime importance, but it has proved of little value in Eastern Tasmania where disproportionate offsets of wall-rock irregularities of the dilational bodies have resulted from connecting cross-dykes. In conclusion it may be noted that unless due regard is given to the possibility of disproportionate offset along intruded masses with irregular walls, erroneous results may be obtained.

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SOME FORMATIONS CLOSE TO THE PERMO-TRIASSIC BOUNDARY IN TASMANIA

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and

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(With three text figures and one plate.)

ABSTRACT

The Cygnet Coal Measures is a unit of carbonaceous shale, coal and feldspathic sandstone in Tasmania of Upper Permian age. It is overlain gradationally or disconformably by the Springs Sandstone, the lower member of which, Barnetts Sandstone, is a thinly-bedded, fine-grained feldspathic to arkosic sandstone, and the upper, the Mountain Lodge Sandstone, a more thickly-bedded, medium-grained protoquartzite. The upper part of the Springs Sandstone is probably Otoceratan. The Permo-Triassic boundary lies within these gradational non-marine units and cannot yet be fixed accurately. The base of the Mountain Lodge Member is probably the most convenient boundary to use as the Permo-Triassic boundary in local field mapping.

INTRODUCTION

Milligan (1849 pp. 17-18) first described the coal measures at Southport subsequently correlated with the Cygnet Coal Measures. Thureau in 1881 mentioned the coal at Cygnet and his description of the section at the coal mines may still be the best. Subsequently Johnston (1887) described coal measures of similar age at Adventure Bay on Bruny Island and in 1888 described the section at Cygnet and correlated both successions with the Newcastle Coal Measures of New South Wales. Subsequently freshwater beds at this level have been recognised widely in Tasmania and sections measured in several places (eg. Mount La Perouse, Hobart, Zeehan, Lake St. Clair, Mole Creek). During 1965, a good succession near the nominal type area was established in detail by I. Naqvi and this led to a review of formations adjacent to the Permo-Triassic boundary.

Difficulty is experienced in many parts of Tasmania in delineating the Permo-Triassic boundary. There is a macrofloral change near the boundary from the *Glossopteris* to the *Dicroidium* flora but pinpointing this change in the field is very difficult because of the poorly fossiliferous character of the formations overlying the Cygnet Coal Measures and their correlates. The standard field convention has been to regard the base of the first thickly bedded quartz sandstone above carbonaceous shales (with or without a *Glossopteris* flora) of the Cygnet Coal Measures as a convenient place for the Permo-Triassic boundary with full recognition that this may not correspond exactly to the Permo-Triassic boundary elsewhere. Lewis (1940) recognised that the important palaeogeographic change occurred at the base not the top of the Cygnet Coal Measure but was not consistent (1946, pp. 22-3).

The difficulties are increased by lack of definition and reasonably precise knowledge of the so-called basal Triassic units. The Ross Sandstone of Bonwick (1870) and later authors is not properly defined in its type area and may be undefinable there. The outcrop is certainly not good in the Ross area. The Rhyndaston Sandstone (David 1932) is much better exposed at Rhyndaston than the Ross Sandstone at Ross, but its relationships to the Permian on the one hand and to younger units on the other are not yet clear. The Springs Sandstone (Lewis 1940) is moderately well-exposed in its basal portions and its relationship to underlying rocks in the type area determinable but not that to younger sedimentary rocks. No accurate section of this formation has been published. Recently the basal Triassic unit in the Lake St. Clair area has been called the Gould Formation (McLeod *et al.* 1961, p. 26), the relationships of which to underlying and overlying units are clear, if gradational, but of which no detailed section has been published. There are, in addition, innate difficulties in defining and correlating units such as the Springs, Ross, Rhyndaston and Gould Formations, because of their depositional environment, probably flood plains with braided channels.

In this paper, definitions and detailed sections of formations near the Permo-Triassic boundary in the Cygnet and Hobart Districts will be offered and the problem of the Permo-Triassic boundary discussed in some detail.

CYGNET COAL MEASURES

Stratigraphy

The nomenclature and synonomy of this formation have been dealt with by Smith (1959, pp. 47-8). The first significant report is that of Thureau (1881) who used the term "Mt. Cygnet measures" and recorded a sandstone floor, 3 ft. of coal, approximately 64 ft. of sandstone, a 5 ft. seam of coal within borders of carbonaceous clay, and a micaceous, laminated sandstone roof. His map and section clearly show two seams separated by sandstone but it is not quite certain that the thickness quoted for the inter-seam sandstone is not excessive due to faulting. Twelvetrees (1902) reported a slightly different section at the Mt.

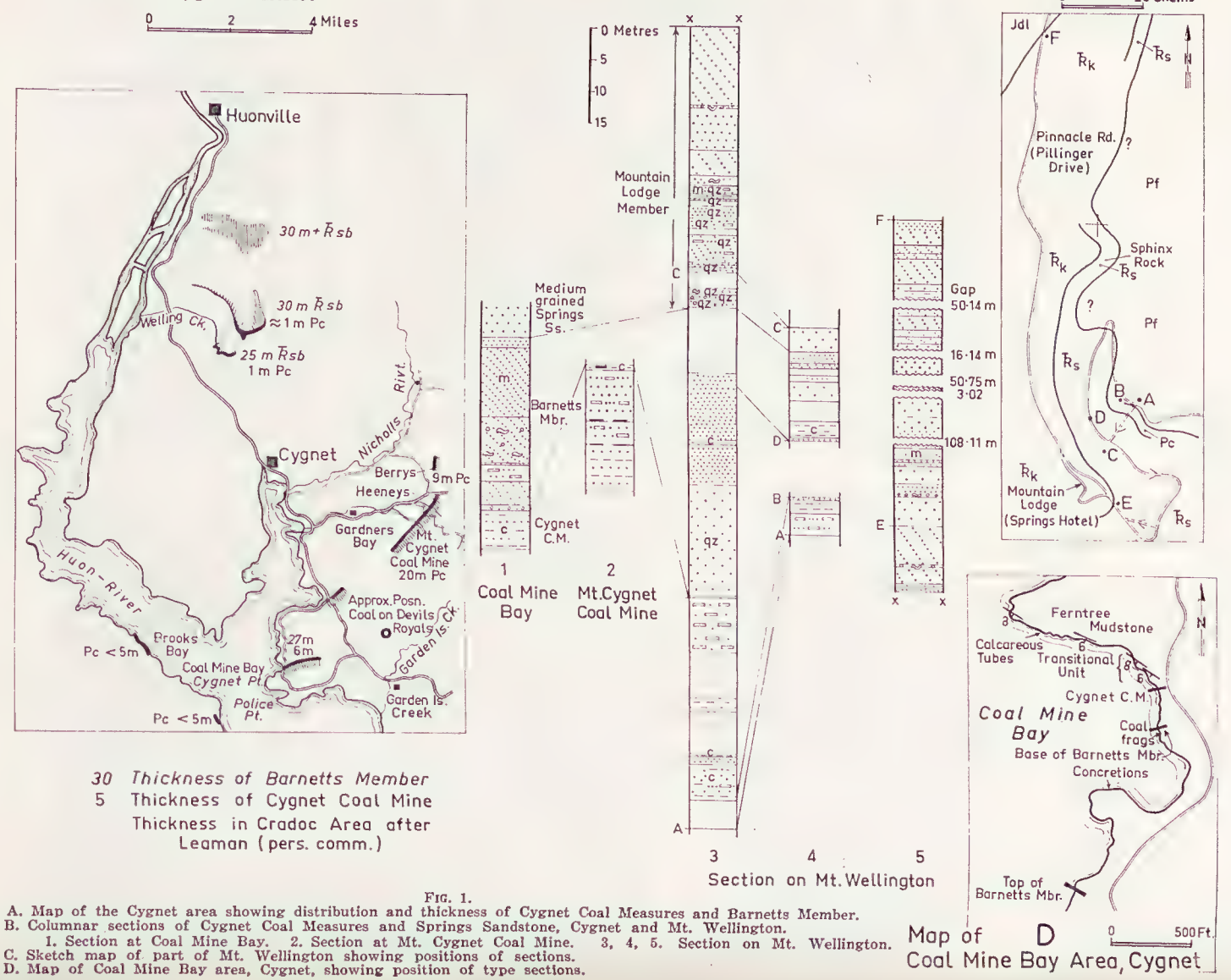

FIG. 1.
A. Map of the Cygnet area showing distribution and thickness of Cygnet Coal Measures and Barnetts Member.
B. Columnar sections of Cygnet Coal Measures and Springs Sandstone, Cygnet and Mt. Wellington.
1. Section at Coal Mine Bay. 2. Section at Mt. Cygnet Coal Mine. 3, 4, 5. Section on Mt. Wellington.
C. Sketch map of part of Mt. Wellington showing positions of sections.
D. Map of Coal Mine Bay area, Cygnet, showing position of type sections.

Cygnet Mines, a small 2 inch seam, another seam 1 ft. thick 12 feet above the first and the main seam 3 ft. thick, 25 ft. above the second. The main and two minor seams of which only one was aceous siltstone, the lower siltstone resting on dark sandstone and the upper with a roof of grey hard, glistening, quartzose sandstone with a conglomerate in places. Reid (in Hills *et al.* 1922) reported two main and two minor seams of which only one was being worked. At Berry's, north-west of the main working (fig. 1 A) a sandstone roof caps a seam 12"-14" thick resting on 12 inches of black shale. This shale rests on 8 feet of shale and 20 feet of sandstone which in turn overlies mudstone. Thus it would appear that in the nominal type area the coal measures are at least 6.8 m. thick and may be over 12 m. thick on Thureau's figures. Recent investigations by the authors show that detailed information in the type area is not available because of thick vegetation and deep soil cover. The Cygnet Coal Measures appear to overlie Ferntree Mudstone, to be between 12 and 18 m. thick and to be overlain by quartz sandstone and thinly-bedded (beds about 1 cm. thick) micaceous sandstones and siltstones.

The best section now available is that in shore platforms at Coal Mine Bay and immediately south (summarised as fig. 1 B, 1). The Ferntree Mudstone with rare erratics and some marine fossils is overlain gradationally by fine-grained carbonaceous siltstone with some sets up to 1.5 cm. thick of interbedded very-fine grained sandstone and carbonacous siltstone in beds up to 2 mm. thick but mostly less than 1 mm. in thickness. Such sets form less than 10% of the basal metre. From 0.9 m. to about 1.1 m. above the base the carbonaceous siltstone contains flow folds ("pseudo-nodules") from 4 cm. x 4 cm. to 6 cm. x 3 cm. and about 0.5 cm. thick consisting of beds less than 1 mm. thick of very fine-grained, white sandstone or coarse siltstone interbedded with carbonaceous siltstone.

A little higher in the section and especially about 1.5 m. above the base larger-scale but otherwise similar structures occur. These structures are up to about 15 cm. long. At about 1.9 m. above the base such structures tend to be the core of concretionary bodies up to 0.6 m. long with a tendency to an east-west orientation of the concretions.

Sandstone becomes more prominent upwards and becomes coarser-grained. A set of cross-bedded sandstone at least 10 cm. thick starts at about 4.8 m. above the base. There are other thinner, but otherwise similar units lower. The 10 cm. set consists of cross-bedded sets 2-3 cm. thick with beds of sandstone and carbonaceous sandstone less than 1 up to 2 mm. thick. Cross-bedding suggests currents mainly from the northerly quarter with rare ones from east or west.

The highest unit recognised is a thickness of at least 0.25 m. of interbedded sandstone (beds about 1-2 cm. thick) and graphitic sandstone and siltstone in beds about 0.5 to 1 mm. thick. There is no coal in this section but the overlying conglomerate contains fragments of coal. An outcrop was recorded and a shaft was sunk on a coal outcrop in the Devils Royals just east of this area (Hills *et al.* 1922, p. 145). At Coal Mine Bay the carbonaceous section is six metres thick and is overlain disconformably by conglomerate with a quartz rich matrix.

No macrofossils occur in this section and unfortunately specimens submitted to Dr. G. Playford, University of Queensland, for palynological study yielded no recognizable spores.

A thin section (33626) of carbonaceous siltstone from the middle of the formation revealed a modal grainsize of the clastic particles between 0.03 and 0.045 mm. with variation from very fine silt to very fine sand. Aggregates up to about 0.4 mm. long of clay grade carbonaceous matter comprise about 30% of the rock, the only other clay grade material being a very minor amount of interstitial clay mineral. Clear unstrained quartz is the commonest constituent of the rock, about 55%, but a little quartz with globular inclusions in lines also occurs. Plagioclase (oligoclase) is about 1% of the rock and there is a surprising amount of biotite (about 12%) and some muscovite (about 3%). The quartz and plagioclase grains are predominantly angular and very few are as rounded as subrounded. Their sphericity varies from equidimensional to very elongate and many have lengths exceeding three times their breadth. The quartz and feldspar grains lie in a felted matrix of biotite and muscovite laths and elongate stringers of carbonaceous matter all held by a minor clay cement.

This section is thinner than that recorded from the Mount Cygnet Coal Mine area (fig. 1B, 2) and apparently differs from it in containing less sandstone. The section on Balfs Hill near Cradoc is even thinner (Leaman 1966). Facies change or subsequent erosion may explain the variations in thickness but the disconformity everywhere present in this area above the coal measures suggests that erosion was the more important factor controlling the thickness locally.

Johnston (1888, p. 203) recorded *Vertebraria australis* and *Gangamopteris spathulata* from shales below the coal at Mount Cygnet and Lewis (1940) amended the record of *G. spathulata* to *Glossopteris* sp. The Cygnet Coal Measures at Cygnet contain spores of the *Dulhuntyispora* Microflora (Balme 1964, pp. 63-4) and from Welling Creek, Cradoc, a number of spore types have been recorded by Dulhunty and Dulhunty (1949) (see Table I).

The Cygnet Coal Measures may thus be defined as that formation about six metres thick at Coal Mine Bay (497.6, 677.7) *of carbonaceous saudstone, carbonaceous siltstone and coal which contains a* Glossopteris *flora and spores of the* Dulhuntyispora *Microflora, overlies the Ferntree Mudstone and underlies a formation of feldspathic sandstone, the Barnetts Member of the Springs Sandstone. It is Upper Permian in age.*

Carbonaceous shale occurs below Triassic sandstone south-west of Huonville (Mather 1955, p. 196) and may represent the Cygnet Coal Measures. A little further west Ford (1956, p. 150) was unable to find any definite Cygnet Coal Measures. South of Cygnet in the Police Point area the Ferntree Mudstone is overlain by black mudstone with quartz pebbles and plant stems and these latter by carbonaceous, micaceous shales (Hale 1953, p. 114)

and at Dover the Cygnet Formation is represented by micaceous, carbonaceous siltstones with some cross-bedding (Hale 1953, p. 113). At Dover and Police Point the contact with overlying rocks is a disconformity, shown by undulatory contacts, increase in heavy mineral content and the presence of pieces of Ferntree Mudstone in the overlying rocks (Hale 1953, p. 117).

East of Cygnet, this formation occurs in the valley of Garden Island Creek, in the bed of Snug Rivulet, and at Gordon (Reid in Hills *et al.* 1922, pp. 145-6) where coal overlies about two metres of carbonaceous shale and underlies sandstone. Still further east the Cygnet Formation occurs at several places on South Bruny Island but the best exposure is that at Adventure Bay, just south-east of the neck, where a fine section is exposed in shore platforms and cliff faces and the coal measures apparently grade up into Triassic sandstones. This section has not yet been adequately studied. Johnston (1886) recorded and later figured (1888, pl. x) two species of *Gangamopteris*, a *Glossopteris* species and fruit and stems.

In the Hobart area Lewis (1946, pp. 35, 95) reported Cygnet Coal Measures from near Silver Falls Creek and in the headwaters of New Town Creek. The formation also occurs below the Springs Hotel where the section (fig. 1B, 3-5) was measured by Banks and Anand Alwar. In that section the Ferntree Mudstone is overlain by a poorly-sorted feldspathic sandstone passing up into interbedded fine-grained, feldspathic sandstone and carbonaceous siltstone both with fragmentary plant remains. Several gaps in outcrop break the succession which is capped by a medium-grained, thickly-bedded, light olive brown cliff-forming sandstone with an estimated feldspar content of 25-30%, thus suggesting that it is an arkose. This is followed after a gap of only 0.5 metres approximately by quartz sandstone, taken, for convenience, as the base of the Springs Sandstone. Carbonaceous shales up to about 10 metres thick were reported by Lewis from Silver Falls Creek and New Town Creek, in the latter area being pyritic and containing wood fragments. Read (1960) reported at least three metres of carbonaceous shale passing up into interbedded carbonaceous shale and fine-grained, cross-bedded, micaeous sandstone with worm burrows overlain by carbonaceous shale from the Sky Farm Road west of Claremont. South of Richmond about 60 cm. of black shale appear to separate Ferntree Mudstone from Triassic sandstone and may be Cygnet Formation (Gatehouse, this volume, p. 2). A metre or so of dark-coloured material separates Ferntree Mudstone from sandstones in sea cliffs north of Eaglehawk Neck on Forestier Peninsula and may represent the Cygnet Coal Measures. No ground survey has been done in the area.

In cliffs and shore platforms on the western shore of Southport a fine section is exposed which probably covers the Permo-Triassic transition. Interbedded feldspathic sandstone and carbonaceous siltstone about 20 m. thick are overlain by a carbonaceous siltstone very rich in *Vertebraria*. This is overlain by 1.5 m. of carbonaceous siltstone, a 2.5 m. gap in outcrop along a pocket beach, one metre of carbonaceous siltstone with thin beds of sandstone, two metres of interbedded carbonaceous siltstone and siliceous sandstone with current ripple marks, 1.25 m. of carbonaceous siltstone, 1.9 m. of interbedded carbonaceous siltstone and some fine-grained, cross-bedded sandstone with slump structures, 0.9 m. of sandstone becoming thinly-bedded and current rippled near the top, 1.5 m. sandstone interbedded at the base with carbonaceous siltstone in beds 1 to 10 mm. thick and capped by 0.25 m. carbonaceous siltstone. This siltstone is overlain disconformably by thickly-bedded, coarsely cross-bedded, medium-grained quartz sandstone at least 40 m. thick which could be taken, for convenience, as the basal unit of the Triassic. These sandstones include a bed about 0.15 m. thick of carbonaceous siltstone with equisetalean stems, the siltstone lying about 20 m. above the base of the thickly-bedded sandstone. Milligan (1849) and Johnston (1893) commented on the sediments from which the latter reported *Vertebraria* and, probably incorrectly, *Pecopteris lunensis*. Twelvetrees (1915, pp. 11-12) gave details of the rocks passed through by a bore starting, presumably, somewhat above the *Vertebraria* bed. These details have been used in constructing column d of fig. 2.

A very good section of the Cygnet Coal Measures is exposed on the northern face of Mount La Perouse. Preliminary studies and measurements have been made by B. F. Glenister and Banks and an approximate section is provided as fig. 3 e. *Glossopteris* and *Vertebraria* are present. The contact with overlying rocks is gradational and the unit shown at the top of the Cygnet Coal Measures, thinly-bedded micaceous sandstone with thickly-bedded, cross-bedded, feldspathic sandstone may be equivalent to the Barnetts Sandstone which overlies the Cygnet Coal Measures at Cygnet.

At Maydena carbonaceous shales 4.5 m. thick are overlain disconformably by 16 m. of feldspathic sandstone (Jago 1965) but on the flanks of the Misery Range about 30 km. north of Maydena the Cygnet Coal Measures are represented by about 30 m. of interbedded carbonaceous siltstone and sandstone lying beneath thickly-bedded quartz sandstone (Corbett 1964).

The thickness of the Cygnet Coal Measures increases northwards to the Lake St. Clair and Pelion Range area (Gulline 1965, McLeod *et al.* 1961) where carbonaceous shale, thin coal seams, feldspathic sandstone, some quartz sandstone and a bed of conglomerate occur. An incomplete section on Mount Inglis is predominantly feldspathic sandstone (Gee 1964).

South-west of Zeehan a thickness of at least 45 m. of cross-bedded, ripple-marked quartz sandstone interbedded with carbonaceous siltstone overlies Ferntree Mudstone disconformably (Banks and Ahmad 1962).

In northern Tasmania, Cygnet Coal Measures (or its correlates Jackey Shale and Clog Tom Sandstone) have been mapped near Mole Creek (Jennings 1963), along the Western Tiers to Poatina (with some breaks) (McKellar 1957), at Beaconsfield (Green 1959) and near Lilydale (Longman 1966). These coal measures may also overlie the Kelcey Tier Beds on the western slope of Bonneys Tier as suggested by comparison of Twelvetrees' plate 2 (1911) with later maps (Burns 1964, p 103), and Brill (pers. comm.) reported coal high on the flanks of Bonneys Tier in Coal Creek.

Rock Types

The Cygnet Coal Measures and its correlates consist of sandstone, predominantly feldspathic but siliceous in many places, carbonaceous and micaceous siltstone and thin seams of coal. Conglomeratic beds are rare but occur at Mount La Perouse, Zeehan and Launceston at the present limits of outcrop of this formation and at Hugel Creek near Lake St. Clair. The sandstones are commonly carbonaceous and in many places are cross-bedded and ripple-marked. No study has yet been made of current directions. The sandstones predominate in most sections especially on Bruny Island, at Mount La Perouse, Zeehan, the Du Cane Range, Mount Inglis, Beaconsfield and Lilydale, again areas close to the present limits of outcrop. Although insufficient sand-shale ratios are available for accurate depiction of variations there is a suggestion that the silt content of the formation is higher at Poatina, Mole Creek, the Pelion Range, some areas near Lake St. Clair, Maydena, Southport, Cygnet and Hobart than around the margins of present outcrop. This in turn suggests derivation from higher source areas not far outside the present limits of outcrop in the north-east, north, north-west, west and south.

The presence of feldspar as a common constituent of the sandstone is unusual. The non-marine sandstones of the Lower Permain Mersey Group do contain feldspar but not in significant amounts and the prominent sandstones of the Lower Triassic are quartz-rich sandstones. No detailed petrographic studies have been made and the type of feldspar not determined.

Coal occurs at Coal Hill near Lake St. Clair, Southport, and Kelceys Tier (probably a single seam at each place) and two or more seams occur on the Pelion Range, Mole Creek, Bruny Island and Cygnet, the thickest known being at Cygnet (1.5 m., Thureau 1881).

Flora

Johnston (1888, p. 143) recorded *Gangamopteris spathulata, G. obliqua, Glossopteris browniana* var. *praecursor* and other indefinite plant remains from Adventure Bay and *G. spathulata* and *Vertebraria australis* from Cygnet (ibid. p. 203). Subsequently Lewis (1940) suggested that the *Gangamopteris* from Cygnet should be referred to *Glossopteris* sp. and Johnston's determinations from Adventure Bay require revision. From Southport Johnston (1893) reported *Vertebraria australis*. McLeod *et al.* (1961, p. 25) reported *Glossopteris, Gangamopteris* and *Vertebraria* near Thetis saddle and Banks and Ahmad (1962, pp. 9-10) recorded these fossils, *Phyllotheca* and *Schizoneura* from the Malanna area, near Zeehan. *Glossopteris* and *Vertebraria* occur in the Mount La Perouse area.

Spores from the Cygnet Coal Measures and their correlates have been reported by Dulhunty and Dulhunty (1949), Balme and Hennelly (1955, 1956a, 1956b), Balme (in Jennings 1963) and Balme (1964), and their distribution is summarised below as Table I

TABLE I

	1	2	3	4
Acanthotriletes tereteangulatus		x		
Anapiculatisporites ericianus	x	x	x	
Anapiculatisporites cf. *ericianus*				x
Bascanisporites undosus				x
Cycadopites vetus	x	x	x	
Deltoidospora directa	x	x	x	x
Granulatisporites micronodosus	x			x
Granulatisporites trisinus	x	x	x	x
Marsupipollenites triradiatus	x	x	x	
Pilaspora plurigenus	x	x	x	
Protohaploxypinus amplus	x	x	x	
Protohaploxypinus sewardi				x
Punctatisporites gretensis			x	
Retusotriletes diversiformis		x		x
Schopfipollenites sinuosus			x	
Striatoabietites multistriatus	x	x	x	x
Striatopodocarpites fusus	x	x		
Thymospora cf. *hamatus*				x

1 = Cradoc (Welling Ck.)
2 = Mount Pelion.
3 = Mole Creek.
4 = Western Bluff.

Taxonomic combinations after Hart (1965).

The spores listed indicate correlation of the coal measures at Cradoc, Mount Pelion, Mole Creek and Western Bluff with one another and with the Newcastle Coal Measures of New South Wales which are Kazanian or Tartarian. The Jackey Shale at Western Bluff in particular is probably equivalent to the upper part of the Newcastle Coal Measures. Balme (*in litt.*) reported that the coal measures at Cygnet, Sky Farm, Hobart and Malanna were of the same age. The Kazanian or Tartarian age is suggested because of the occurrence of the same *Dulhuntyispora* assemblage in the Condren Member of the Liveringa Formation of Western Australia, underlain by the Lightjack Member with goniatites of Upper Artinskian or Lower Kungurian age (Glenister and Furnish 1961, p. 688) and overlain by the Hardman Member with *Aulosteges ingens* and *Waagenoconcha imperfecta* which occur in the Basleo Beds of Timor and are similar to species in the Kazanian of Russia (Coleman 1957, p. 139) thus suggesting a Kazanian age. The spores from the Newcastle Coal Measures may however range beyond the limits of the Condren Member but are clearly pre-Scythian.

Stratigraphic Relationships

The stratigraphic relationships of the Cygnet Coal Measures as here used are summarised in fig. 2. In north-eastern and eastern Tasmania the formation is missing. A disconformity is found at the base of the formation in northern and western Tasmania whereas in the central and southern parts of the basin, where the formation is thickest, the basal contact is conformable. This, with the smaller grainsize in the central parts of the basin, suggests lower stream velocities, and probably grades) in those areas, indicating perhaps a low-lying, flattish central area bounded by low, rather distant hills.

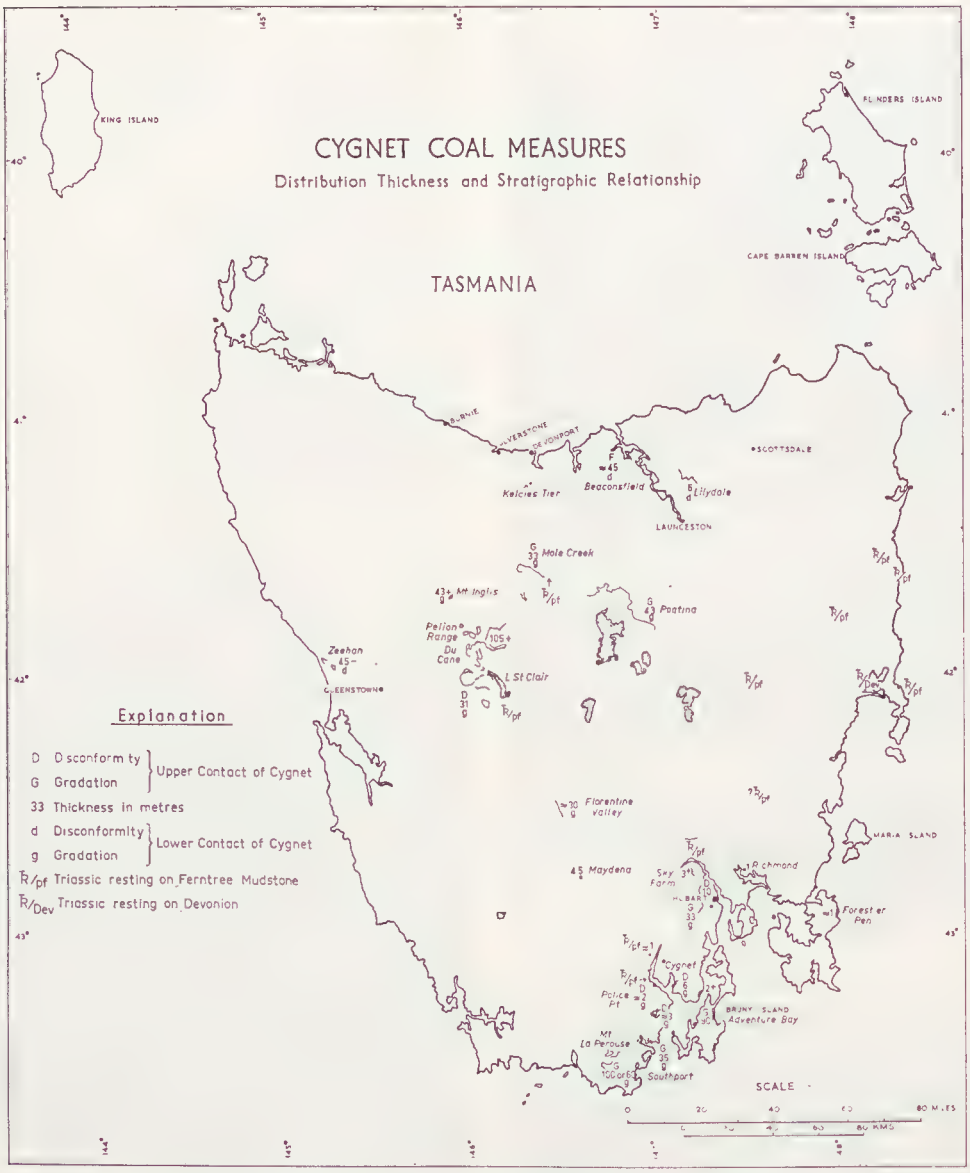

FIG. 2.—Map of Tasmania showing distribution, thicknesses and stratigraphic relationships of the Cygnet Coal Measures.

The upper contact shows less systematic variation in its character although again gradation occurs in most of the thicker sections and disconformity in the thinner. Variation in thickness of the formation and type of upper contact in the area around Cygnet suggests considerable differential erosion and possibly uplift before deposition of the overlying Barnetts Sandstone (see fig. 1 A).

The thickness of the formation varies up to about 105 m. but measured sections are exposed too sporadically to make construction of useful isopach maps possible in view of the likely effects of disconformities and until detailed correlations between sections become feasible. A zone of thicker Cygnet Formation appears to extend from south of Zeehan through the Du Cane and Pelion Ranges to Mole Creek, Poatina and Beaconsfield but this has an area within it at Westmoreland Creek, just east of Mole Creek, where Triassic rocks rest directly on Ferntree Mudstone (Jennings 1963). Another zone of thicker sediments appears to extend from Mount La Perouse through Southport to Bruny Island and Hobart.

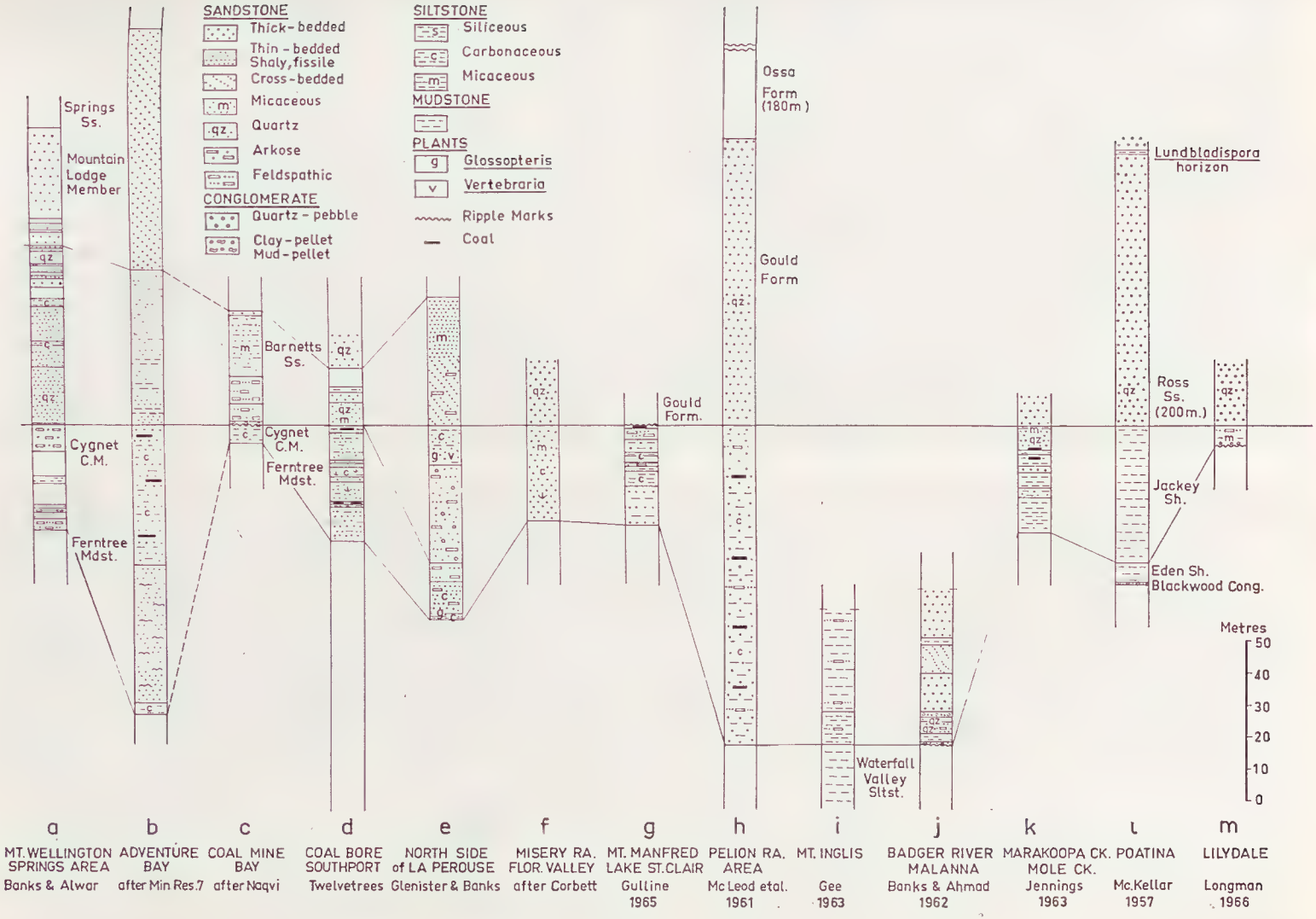

FIG. 3.—Columnar sections of the formations close to the Permo-Triassic boundary in Tasmania.

SPRINGS SANDSTONE

The name was first used, casually, by Lewis (1940) and explained more fully by Lewis (1946, pp. 23, 35) by whom the thickness on Mount Wellington was given as 800 feet, 200 feet more than the average elsewhere. Elsewhere in that publication (*Ibid.* p. 46) the thickness was given as 500 feet, or even, it would appear, 1,000 feet (p. 67). It was described as massive sandstone. Lewis did not define the term very stringently and it is not clear if he considered the Springs Sandstone as only the cliff-forming sandstone or as all the rock between the Ferntree Mudstone and the dolerite contact on the Pinnacle Road.

A section was measured from the top of the Ferntree Mudstone on the Pinnacle Road to the dolerite contact (fig. 1 C) by M. Anand Alwar and one of the authors (M.R.B.) some years ago and is recorded here as figs. 1 B, 3, 4, 5, and the lower part of it as fig. 3 A, and in more detail in an Appendix. The cliff-forming, "massive" sandstones below the Springs Hotel (A-E on fig. 1 C) form a distinctive mappable unit above which the section is very discontinuous.

It is proposed therefore to define the Springs Sandstone as that unit of quartz sandstone with minor siltstone and clay-pellet conglomerate overlying the Cygnet Coal Measures and underlying a unit of sandstone and siltstone, probably equivalent to the Knocklofty Sandstone and Siltstone, in track, road and cliff sections below the Springs Hotel. It is about 92.5 *m. thick in its type section.* (511.45 *E.* 717.05 *N. to* 511.52 *E.* 716.53 *N.*). *No fossils have been recorded in it from its type section but it is probably Lower Triassic.*

In its type area it may be considered as consisting of two members, a lower one about 55 m. thick of sandstone, especially sandstone with beds of the order of 10 cm. to a few tens of centimetres thick and fissile sandstone, siltstone and rare clay-pellet conglomerate, the upper one about 37.5 m. thick of coarsely cross-bedded cliff-forming sandstone in beds mostly of the order of one metre thick. The lower member may be correlated with the Barnetts Member, well-exposed in cliff and shore-platform sections south of Coal Mine Bay, Cygnet.

Unit G (see Appendix) may conveniently be taken as the base of the upper member in the track section "A"-"C" and unit j in the road section "D"-"C". The lower member consists predominantly of well-sorted medium to fine-grained sandstones with minor developments of coarse-grained sandstone near the base, and some carbonaceous siltstone with plant fragments. The sandstones consist predominantly of quartz with minor quantities (<10%) of muscovite, graphite and feldspar. They are cross-bedded and have beds a few centimetres to about 75 cm. thick and some are fissile. The carbonaceous siltstone contains plant fragments (probably sphenopsid), sandy beds a few millimetres thick and some clay pellets. Outcrop of this member is somewhat subdued in contrast to the strong development of cliffs by the upper member.

The upper member, which may be called the Mountain Lodge Member, outcrops well in the cliffs beneath the Springs Hotel and at Sphinx Rock. It may be considered to include units G to Y in the road, track and cliff sections between "C" and "E" (fig. 1 C). The main rock type is a well-sorted, medium to coarse-grained quartz sandstone, cross-bedded and with beds generally more than 75 cm. thick but with some units more thinly bedded.

Current ripple marks occur on some bedding planes and suggest currents from the northerly quarter. The cross-bedding suggests currents from northerly, westerly or south-westerly areas. The cross-bedding commonly shows current drag effects at the top of the set. The predominant mineral is quartz, often with sparkling surfaces which are crystal faces resulting from authigenic outgrowth, with very minor amounts of muscovite, graphite and feldspar (<2%). Clay-pellet and quartz pebble conglomerates also occur. A few grains of pink garnet were seen by hand-lens in the basal unit.

The section above the Springs Sandstone, as here used, on the Pinnacle Road reveals sandstones and some siltstones, the sandstones finer-grained and more thinly-bedded on the whole than those in the Mountain Lodge Member. Some beds with 10%-20% feldspar occur and a green micaceous mineral, probably a chlorite, occurs on several horizons. Cross-bedding is common and ripple-marking present. Dips of cross-bedding appear to be too variable to allow assessment of current directions without statistical analysis.

Fossils have not been found in any of the units in this section. The Mountain Lodge Member is like the lowest sandstone units in the Knocklofty Formation a few miles to the east and these sandstones are overlain by fossiliferous siltstones of Scythian age. The most likely age for the Springs Sandstone is Scythian but there is no reliable, direct evidence for this.

In the Coal Mine Bay area near Cygnet, the Cygnet Coal Measures are overlain by a sandstone formation, divisible into a lower member called the Barnetts Sandstone and an upper member, lithologically similar to the Sphinx Rock Member of the Hobart area.

The Barnetts Sandstone may be defined as the lower member of the Springs Sandstone disconformably overlying Cygnet Coal Measures at Coal Mine Bay. It consists of 27 *m. of feldspathic sandstone, and is named for Barnetts Trig. Point* (498.20, 678.00) *near Coal Mine Bay. It is probably Triassic but may be Upper Permian.*

The section of the formation (see fig. 1 B and Leaman & Naqvi 1967) commences with a basal conglomeratic unit (plate 1, f. 1) about one metre thick, consisting of granule and pebble conglomerate, feldspathic sandstone and thin beds (1-2 mm.) of coal and carbonaceous siltstone. The granules and pebbles are composed of quartz, carbonaceous siltstone, a mudstone (probably Ferntree Mudstone), and rarely of schist. Most of the larger fragments are 3-4 cm. long but some of the angular fragments of carbonaceous matter lying across the bedding reach a length of 10 cm. The matrix consists of angular quartz fragments with a minor clay cement. Quartz comprises about 60% of the rock. Kaolinised feldspar in the matrix comprises about 10% of the rock. Muscovite and graphite are common, and rutile, limonite and distinctive patches of pink garnet are present. The conglomerate is disconformable on the Cygnet Coal Measures. The conglomerate is cross-bedded, the current having come from 50°.

Above the conglomerate is a bed of coal and carbonaceous shale nine cm. thick and at least three metres long (plate 1, f. 2, 3). In places just below the coal is a bed five cm. thick of interbedded sandstone and carbonaceous siltstone like that immediately beneath the basal conglomerate. The sandstone and siltstone unit passes west into a unit up to 30 cm. thick of interbedded coal, carbonaceous siltstone and sandstone (plate 1, f. 3).

A fine to medium-grained, fairly well-sorted sandstone overlies the coal and, where coal is absent, the basal conglomerate. This is cross-bedded, the individual laminae being a few millimetres to a few centimetres thick, and in the top part ferruginous concretions form up to 2% of the rock. The sandstone (33624 in the University of Tasmania Geology Department collection) consists of angular and a few subangular grains of quartz (about 50%), kaolinised plagioclase (about 30%) which is oligoclase where it is determinable, some microcline (1%), muscovite (5%) and a few quartzite fragments in a limonitic (10%) and sericitic (5%) cement. The clastic grains are equidimensional to elongate (length up to five times breadth) and are fine sand (modally) but range from medium silt grade up to coarse sand grade. The quartz is predominantly clear and unstrained but some with undulose extinction is present. A few sand grade grains of zircon and rutile occur. The framework is closed. Many quartz grains have sutured contacts against one another whereas the boundaries of others appear to be sericitised. The ferruginous cement seems to have been emplaced before development of the sericite in most places but in a few the sericite appears to be earlier. The rock is an arkose.

This richly feldspathic sandstone is overlain by thinly-bedded (beds a few cm. thick) feldspathic sandstone (33623) with pieces of carbonaceous siltstone like that of the Cygnet Formation forming about 8% of the rock. At the top of this unit is a bed 17 cm. thick of conglomerate of which up to 75% comprises this siltstone (plate 1, f. 4). A thin section of the sandstone showed the following composition: quartz, mainly unstrained, some with undulose extinction, some with lines of globular inclusions, 60%; rock fragments, quartzite, siltstone, micaceous siltstone, 5%; feldspar, mainly plagioclase not determinable with certainty, some microcline, 20%; muscovite, 2%; carbonaceous matter, 1%; ferruginous cement, 7%; sericitic cement, 5%; rutile, tourmaline, zircon in small quantities. The framework is closed and the rock consists of angular to subangular and a few subrounded fragments most of which are nearly equidimensional but a few have lengths up to four times the breadth. The modal grade is fine sand and particles range in size from coarse silt to medium sand. Some boundaries between quartz grains or between quartz and feldspar grains are sutured but ferruginous or sericitic cement separates others.

The next unit is a pale red to purple, fine-grained, well-sorted, strongly cross-bedded (plate 1, f. 5) feldspathic sandstone (33622). Examination of a thin section showed that the rock consists of quartz (about 65%); fresh and sericitised feldspar (oligoclase where determinable, 5-7%); muscovite (5-7%), fragments of very fine-grained quartzite, siltstone and clay (3%), graphite (1%) and a few grains of zircon in a matrix of ferruginous material (7%), kaolin (3%) and felted masses of sericite (10%). The clastic particles are mainly equidimensional although a few quartz grains and some muscovite laths appeared to have length about four times breadth. The grains are angular and subangular but a few are subrounded. The framework is intact. The modal grainsize is fine sand with very little coarse sand, much medium sand and very fine sand and some coarse silt. A few lenses of clay pellet conglomerate occur in this sandstone. The cross-bedding indicates currents from the northwest.

A reddish, fine-grained, well-sorted, fissile, quartz sandstone (33621) overlies the feldspathic sandstone. This rock is predominantly quartz (80%) with very little muscovite (2%) and plagioclase (2%) which is probably oligoclase. The clastic grains are predominantly in the fine sand grade, a few only in the medium sand grade, some in the very fine sand and little, if any, in the coarse silt grade. The framework is intact, made mainly of angular, equidimensional quartz grains with a few quartz and muscovite grains about three times as long as broad. Many of the quartz grains have sutured contacts but others are separated by a felted sericitic matrix composing ten to fifteen per cent of the rock.

The final unit is a thin, transitional bed of medium-grained, well-sorted, finely laminated sandstone (33620) which consists of quartz (75%), feldspar (sericitised, 10%), muscovite (3%), graphite (2%) and an iron-rich argillaceous matrix.

This member differs significantly from other rock units in the abundance of feldspar, the good sorting, the thinly-bedded, cross-bedded units and the abundance of small, spheroidal ferruginous concretions. The abundance of clay pellets at Coal Mine Bay helps to differentiate it from the overlying member. The pellets are discoidal to ellipsoidal structures up to eight cm. long and although the majority are siltstone, some are of feldspathic sandstone, suggesting contemporaneous erosion. Graphite from this member was examined by X-ray diffraction methods and its identity established.

The quartz sandstone conformably and transitionally overlying the Barnetts Member at Coal Mine Bay (plate 1, f. 8) is at least 27 m. thick in this and the Randalls Bay area. It is medium-grained, well-sorted, cross-bedded with beds of the order of one metre or more in thickness. Limonitic concretions and clay pellets are present but not so common as in the Barnetts Member. The rock (33619) consists of angular and subangular quartz particles (80%), muscovite (5%) and fragments of siltstone, carbonaceous siltstone, and some fine-grained sandstone (10%) with common particles of zircon, rutile and tourmaline with a minor cement of felted sericite laths (about 5%). Many of the quartz particles showed sutured, almost stylolitic, contacts with other particles. Most of the quartz is equidimensional but a few particles up to four times as long as broad occur. The quartz grains are predominantly of clear, unstrained quartz but some strained quartz, some quartz with rutile needles and some with euhedral zircon crystals and lines of inclusions occur. A few grains may show signs of regrowth. The tourmaline in this

as in other thin sections from the Barnetts Member is green. The zircons are predominantly euhedra or broken euhedra. Limonite staining is present but minor. The grains are mainly in the medium sand grade with some coarse, some fine and some very fine sand particles. Tourmaline, ilmenite, melanite and some zircon and magnetite were separated as heavy minerals and comprise in all about 0.2% of the rock. This member corresponds in character and position to the Mountain Lodge Member in the Hobart section.

Rocks apparently similar in character to the Barnetts Member and overlain by thickly-bedded, usually cliff-forming quartz sandstones have been reported by Mather (1955, pp. 96-7) from the Huonville area, and Hale (1953, p. 122) from Brooks Bay where they are 45 m. thick and overlain by cliff-forming quartz sandstone between 30 and 45 m. thick; from the Police Point area (*Ibid.* pp. 122-3) and from the eastern shore of Port Esperance (*Ibid.* p. 124). An outcrop on the Esperance River south-west of Geeveston (Ford, 1954, p. 155) may be a correlate of the Barnetts Member. Further afield the top 40 m. of the section beneath the thickly-bedded sandstones on Mount La Perouse may correspond to the Barnetts Member and 15 m. of feldspathic sandstone overlies carbonaceous siltstone near Maydena and may be a correlate of the Barnetts Member (Jago 1966).

Neither the Barnetts Member nor the overlying member at Coal Mine Bay has yielded fossils.

The Barnetts Member in its type area has some unusual features. The second unit (33624) is an arkose with a high proportion of kaolinised plagioclase and very few rock fragments. Its composition and texture suggest relatively short transportation by water from a terrane of granitic and metamorphic rocks. Higher units contain progressively less feldspar. Although in each case the modal grade is fine sand, the estimated mode decreases from about 0.2 mm. (33624, 33623) to 0.15 mm. (33622) and 0.12 mm. (33621), and the range in grainsizes decreases in general from six grades (33624) to four (33623, 33621), and an impression of better sorting and longer transport emerges from this preliminary study. No change in terrane during deposition of this member is evident. The cementing material in all sections studied is sericitic and ferruginous.

The upper member at Coal Mine Bay shows a marked increase in modal grainsize (about 0.35 mm.) and in the size of the coarsest fragment present (1.1 mm.), with a continued decrease in the feldspar content. The current velocity of the depositing streams apparently increased but feldspar was no longer available in the source area due to deep weathering of quartzo-feldspathic rocks or to the earlier source of feldspar having become covered.

Correlations

Suggested correlations, based on lithological similarity and stratigraphic position are shown in fig. 3. The most significant point emerging from these correlations is that if correlation with the Ross Sandstone at Poatina is correct, the Springs Sandstone is Scythian and may be roughly correlated with the Knocklofty Formation which contains two spores of stratigraphic significance also present in the Ross Sandstone. Thus at Cygnet and Hobart the Permo-Triassic boundary lies within the range of the Cygnet and Springs Formations.

THE PERMO-TRIASSIC BOUNDARY IN TASMANIA

Evidence has been presented earlier that the Cygnet Coal Measures are Upper Permian, contain the *Dulhuntyispora* Microflora, and at Western Bluff at least may be correlated with the upper part of the Newcastle Coal Measures of New South Wales. A siltstone 85 m. above the base of the Ross Sandstone at Poatina contains *Lundbladispora brevicula* and *Densoisporites playfordi* (Playford 1965) and a siltstone at Crisp and Gunn's Quarry, Knocklofty, in the Knocklofty Formation also contains these spores (G. Playford *pers. comm.*). The presence of these spores suggests correlation with the Collaroy Claystone of the Narrabeen Group of New South Wales (Evans 1966) and with the Kockatea Shale of Western Australia (Playford 1965) which is Otoceratan (basal Scythian). The two lower spore assemblages (TR 1a, TR 1b) reported from New South Wales and Queensland (Evans 1966) have not yet been found in Tasmania. In New South Wales the thickness of sediment separating the Collaroy Claystone from the Newcastle Coal Measures is nearly 400 m. (Hanlon *et al.* 1953) considerably more than that between the *Lundbladispora* horizon and the Jackey Shale. At this stage it is impossible to fix with any precision the boundary in Tasmania corresponding to the base of the Narrabeen Group in New South Wales, and, of course, to divide the Tasmanian succession accurately in terms of a world standard Permo-Triassic boundary (top of the *Cyclolobus* Zone).

For local convenience in field mapping this boundary has been taken at the base of the first thickly-bedded sandstone above the highest carbonaceous siltstone. This may well correspond to the base of the Sphinx Rock Member as both on Mount Wellington and at Cygnet the Barnetts Member contains carbonaceous siltstone, is relatively thinly-bedded and has a subdued outcrop whereas the Sphinx Rock Member outcrops boldly and the obvious place for a field mapping boundary is at the base of this member. The entry of cross-bedded, feldspathic sandstones is probably not a suitable horizon for distinguishing the Cygnet from the Springs Formation as the Cygnet contains feldspathic sandstones in many places although at others, e.g., Malanna, it does not seem to have significant quantities of feldspar. The base of the Barnetts Member is a convenient boundary as, in some places at least, there is a disconformity and a thin conglomerate at this level. However, in the type areas and elsewhere the conditions of deposition did not change significantly at this horizon; coal and feldspathic sandstone occur both above and below the contact. In addition, disconformities, even those overlain by thin conglomerates, within fresh-water successions may well be of very local extent and short duration. Angular unconformities between the Ferntree Mudstone and Springs-type sandstone have been reported by Woolley (1959) and Alwar (1960) but the evidence is not incontrovertible. Attempts to

determine the age of this boundary at Cygnet and Southport by palynological studies failed because of poor preservation of spores. Disappearance or virtual disappearance of feldspar from the section does not appear to be a good criterion for separating Barnetts and Mountain Lodge Members as this seems to have occurred at different levels in different places. In fact, some of the sandstones above the Mountain Lodge Member on Mount Wellington appear to contain considerable quantities of feldspar. The appearance and disappearance of feldspar is probably related to uncovering and covering of different source areas at different times. At Cygnet and elsewhere the contact between Barnetts and Mountain Lodge Members appears to be gradational and the main objective criteria for distinguishing them are bedding thickness, grainsize and outcrop behaviour.

Finally, delineating formations in a persistent fluvial environment is very difficult just because of the environment and no less difficult if the fluvial environment changes slowly with time as may be suggested for the interval from Cygnet to Mountain Lodge.

Thus no *a priori* case can be established for preferring the base of the Barnetts to the top of the Barnetts as a system boundary and neither may correspond to the top of the *Cyclolobus* Zone. A floral change occurred at about the time of deposition of the Barnetts Member and establishment of the position of this change in different sections may eventually provide a better time marker than is now available. As is widely realized by Australian palaeontologists this change itself may not correspond to the system boundary elsewhere.

CONCLUSIONS

The Cygnet Coal Measures of Upper Permian age are followed disconformably or gradationally by the Springs Sandstone, the basal member of which, Barnetts Sandstone, is thinly-bedded, fine-grained and in places arkosic and the upper member, Mountain Lodge Member, a more thickly-bedded, coarser-grained protoquartzite. The Springs Sandstone has few identified fossils but by correlation with the Ross Sandstone is probably basal Triassic (Otoceratan). The most convenient horizon to take as the Permo-Triassic boundary in Tasmania is probably the base of the Mountain Lodge Sandstone but this is debatable and certainly may not correspond temporally to the Permo-Triassic boundary elsewhere.

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Appendix I

Section from Dolerite Contact on Pinnacle Road to Cygnet Coal Measures

TOP—dolerite contact, "F" on fig 1 C

Unit

F_2 1.20 m. fiss., fine-gnd ss and coarse sltst, 10 Y R 6/6.

E_2 2.73 m. c.b. ss, cross-bedded sets approx 5 cm. thick; beds of order or one m. thick.

D_2 1.36 m. very fine-gnd ss, cross-bedded sets abt 10 cm. thick; beds 10 to 30 cm. thick approx.

C_2 0.91 m. bed of qz ss with some feld; base cross-bedded.

B_2 4.12 m. fine-gnd qz ss with some graph; fiss, c.b.

A_2 1.06 m. ss with beds of order of 30 cm. thick.

Z_1 1.21 m. coarse-gnd sltst, beds 7:5 to 25 cm. thick; non-fiss; 5 Y 6/4.

Gap of 50.14 m.

Y_1 1.21 m. c.b. ss; sets 2.5 cm. thick; cross-bedding dips 207° at 15°.

X_1 2.12 m. thick bedded (beds about 0.75-1 m. thick) ss.

W_1 1.06 m. med to fine-gnd, c.b. ss, containing qz, feld, musc; c.b. sets 10-12 cm. thick; c.b. dips 170° at 12°, 5 B G 6/2.

V_1 1.06 m. c.b. ss with discoidal ferruginous clay concretions up to 2.5 cm. long; c.b. sets 0.5 to 2.5 cm. thick, thinner near base; thicker near top.

U_1 0.91 m. thick bedded ss.

Gap of 16.14 m.

T_1 2.74 m. med-gnd ss; qz, musc; feld uncommon; beds 30 cm. to 1.25 m. near base, 2.5 to 5 cm. thick near top; 10 Y 6/2 or 5 BG 5/2.

Gap of 50.75 m.

S_1 0.61 m. med-gnd ss with qz, musc, graph, feld (<5%); c.b.; bedding 15 cm. to 20 cm. thick.

Gap of 3.02 m.

R_1 2.25 m. friable med to coarse-gnd ss.

Q_1 0.60 m. med to coarse-gnd ss, qz, feld (abt 10% some fresh), beds 22-40 cm. thick.

P_1 0.35 m. coarse to med-gnd sltst, qz, musc, graph, very fiss.

O_1 3.50 m. f to med-gnd ss, qz, feld (5%), musc, clay pellets, bedding up to 1.25 m. thick; 10 YR 6/6.

Gap of 108 m.

N_1 0.76 m. fine-med-gnd ss, qz, musc, feld rare, single bed, friable; 10 YR 7/4.

M_1 2.29 m. c.b. ss; basal part with sets 0.5 to 1 cm. thick, overlain by ss with eroded current ripples, clay pellets and current drag; c.b. dips 310° at 16°; overlain by c.b. ss sets 7.5 to 10 cm. thick.

L_1 0.46 m. one bed ss.

Unit

K_1 0.61 m. ss, beds order of few cm. thick.

J_1 2.74 m. med to fine-gnd ss, qz, musc, feld (<5%), graph uncommon, green biot or chlor, beds 7.5 cm. to 1 m. thick; 10 YR 4/2.

I_1 0.75 m. med.gnd ss, musc, feld (>5%); c.b. sets 2.5-5 cm. thick, c.b. dipping 130° at 12°; 10 YR 6/6.

H_1 0.75 m. clay-pellet conglom.

G_1 0.75 m. med-fine gnd ss, qz, musc, graph, feld (<5%); beds 0.5-10 cm. thick, 10 YR 6/6.

F_1 4.42 m. med-gnd ss, qz, feld, musc, graph, clay pell. up to 5 cm. long 5 Y 5/2; beds up to 2.5 m. thick.

Second road to chalet above Mountain Lodge.

Gap of 17.22 m. including first road to chalet above Mountain Lodge.

"E" on fig. 1.

E_1 0.45 m. med-gnd ss, qz, feld (<5%), musc (rare), graph, green biot, or chlor; contains large rounded frags up to 5 cm. long which look like Fern-tree Mudstone and garnetiferous ? phyllite; bedding up to 2.5 cm. thick; c.b., 10 YR 8/2.

D_1 5.50 m. ss, beds up to 1 m. thick.

C_1 0.07 m. 6 beds, each less than 0.5 cm. thick of clay pellet conglom; pebbles up to 1 cm. long in arenite (gns up to 1 mm.) matrix, qz, feld (5-10%); (some bands up to 20% feld and in these gns are more angular than in others), musc, rare graph, chlor; beds of conglom lenticular, 10 YR 4/2.

B_1 2.40 m. ss.

A_1 0.60 m. med-gnd ss, qz, feld (5-10%), musc, graph (rare), beds 45-15 cm. thick, 10 YR 6/6.

Z 1.20 m. fiss, fine-gnd ss with qz, musc, feld, graph, in beds 0.5 to 6 cm. thick; ripple marked, 10 Y 6/2, interbedded with coarse-gnd sltst, 5 Y 5/2, with ? animal tracks.

Y 14.94 m. c.b.; ss beds 30 cm. and more thick; current drag structure present; cliff forming; some small ferrug, concretions.

X 0.30 m. ss, beds 0.5 to 2.5 cm. thick.

W 0.02-0.05 m. clay pell and qz conglom; pell up to 7.5 cm. long; changes along strike to N.

V 6.70 m. ss, beds abt 1 m. thick; cliff-forming.

U 3.94 m. c.b. ss, sets 20 cm. thick; c.b. dips 25° at 17°.

T 1.50 m. 10 R 6/2 ss, few clay pellets; top with current ripples from north; beds about 0.9 cm. thick.

S 0.05 m. fine-gnd fiss ss; beds approx 1 cm. thick; qz, musc, graph.

Unit

R 1.60 m. med-gnd ss, qz, musc (rare), feld (rare) clay pell (rare), c.b. beds 0.5 to 1 cm. up to 60 cm.; 10 YR 5/4.

Gap of 0.4 m.

Q 0.50 m. one bed ss.

P 0.15 m. ss, qz, musc, graph; beds <0.5 cm. thick.

Gap of 1.2 m.

O 1.60 m. fine-gnd ss, qz, musc, graph; bedding 2.5 cm. thick.

N 1.60 m. fine to med-gnd ss, qz, musc, graph, feld (<5%); beds 0.5-1 cm.; c.b. with dip 90° at 13°, 10 YR 6/6.

Gap of 1 m.

M 4.60 m. med-gnd ss, qz, graph, feld (<2%); beds 15-60 cm. thick, c.b.; cliff forming, 10 YR 6/6.

L 0.20 m. friable white ss.

K 0.20 m. c.b. fiss ss, fine-gnd, qz, graph, musc, one set.

Third step on track above road at "C" (fig. 1 C).

"C"—"D"

l 1.80 m. ss, qz, musc, graph, clay pell, beds 7.5 to 15 cm. thick.

k 0.15 m. c.b. ss, qz, graph, musc.

j 1.70 m. med- coarse-gnd ss, beds 0.8-1 m. thick; with qz, graph, clay pell near top; near base sets 7.5 to 30 cm., c.b. with current drag; 10 YR 6/6; ss.

i 1.50 m. fine-gnd ss, musc, qz, beds 0.5-2.5 cm.

h 0.30 m. c.b. ss, sets 1-2.5 cm. thick.

g 0.45 m. one set c.b. ss.

f 0.30 m. fine-gnd ss, qz, musc, graph, beds 1.0-2.5 cm.

Gap of 0.75 m.

e 0.60 m. med-fine gnd ss, qz, musc, graph, 10 YR 6/4.

Gap of 0.30 m.

d 0.15 m. c.b. ss; sets 1-2 cm. thick.

c 2.25 m. ss, beds 75 cm. thick.

b 0.60 m. ss.

Gap of 3.5 m.

Unit

a 2.59 m. med-fine gnd sltst, qz, musc, feld, rare plant frags, non-fiss; irregular blocky fracture.

"D"

"C"-"A"

J 0.90 m. ss, beds more than 30 cm. thick.

Road (approx 2.45 m. gap).

I 1.25 m. med to coarse-gnd ss, with clay pell, c.b., qz, feld (<5%), musc (rare), graph (rare), beds 10 cm. or more thick.

H 0.50 m. fine-gnd qz, clay pell conglom.

G 1.50 m. med to coarse-gnd ss, qz, feld (<5%), musc (rare), graph (rare), pink garnet (very rare), beds 10 cm. or more thick; some conglom bands 10 YR 6/6.

Gap of 10.36 m.

F 10.67 m. fine-gnd ss, qz, musc, beds less than 1 cm. thick, very fiss near base, less so near top 5 Y 5/2.

E 1.50 m. med to coarse-gnd, carb sltst with qz, musc, feld, plant frags (? sphenopsid), some beds fine-gnd ss and clay pell conglom, somewhat fiss, N4-N5.

D 6.40 m. very fiss, micaceous, fine-gnd ss, beds less than 1 cm. thick, 5Y 5/2.

C 1.20 m. ss, beds 1-1.5 mm. thick, 5 Y 7/2.

B 1.70 m. ss, beds 1-2.5 cm. thick; otherwise as A.

A 14.60 m. med. to coarse-gnd ss, qz, feld (<10%), musc, graph, 10 YR 8/4.

Base of Springs Sandstone on track from "C" to "A" on Pinnacle Road (Pillinger Drive).

Thicknesses by abney levelling or by measurement on outcrop by steel tape.

Abbreviations.—*biot*—biotite; *c.b.*—cross-bedded or cross-bedding; *chlor*—chlorite; *conglom*—conglomerate; *feld*—feldspar; *ferrug*—ferruginous; *fiss*—fissile; *frags*—fragments; *gnd*—grained; *graph*—graphite; *med*—medium; *musc*—muscovite; *pell*—pellet; *qz*—quartz; *rnded*—rounded—*sltst*—siltstone; ss—sandstone.

Colour symbols quoted are from *Rock Colour Chart*, Goddard *et al.*

EXPLANATION OF PLATES.

1. Basal conglomerate with cross-bedding, Barnetts Member in type section; note coal lense immediately above it in right-hand side of photograph.

2. Coal lense between basal conglomerate and second unit of Barnetts Member.

3. Second unit of Barnetts Member in type section shown basal conglomerate at lower left passing up and right in interbedded feldspathic sandstone, carbonaceous siltstone and coal; second unit at top of photograph.

4. Clay pellet conglomerate, Barnetts Member, Coal Mine Bay.

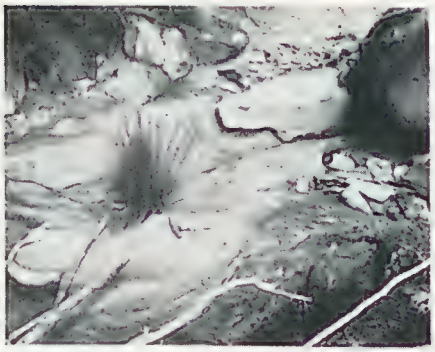
5. Cross-bedding and ferruginous concretions, Barnetts Member, Coal Mine Bay.

6. Thinly-bedded sandstone showing diffusion rings and weathering pattern, Barnetts Member, Coal Mine Bay.

7. Thinly-bedded sandstone, Barnetts Member, Coal Mine Bay.

8. Contact between Barnetts Member below and thickly-bedded, cross-bedded sandstone above as seen in cliff section at Coal Mine Bay 493.3, 677.42. Hammer lying immediately below contact.

[Photos by A. Goede for I. H. Naqvi.



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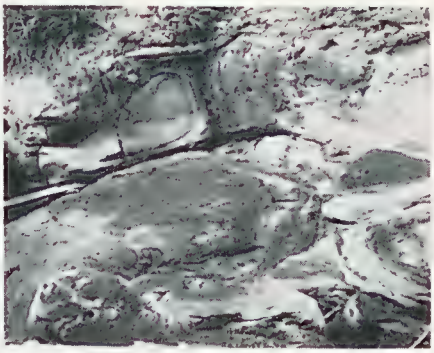

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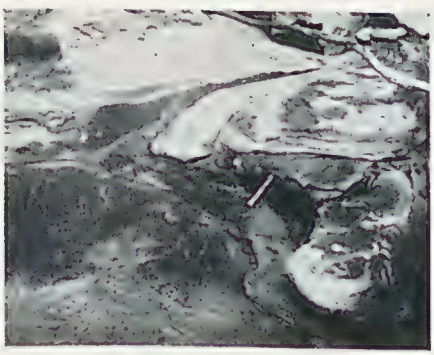

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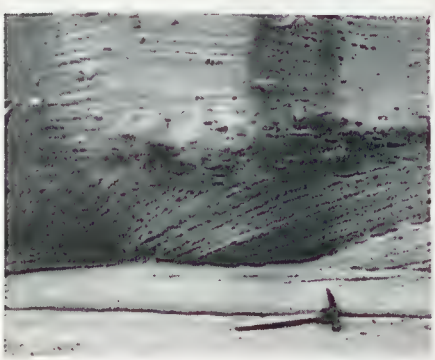

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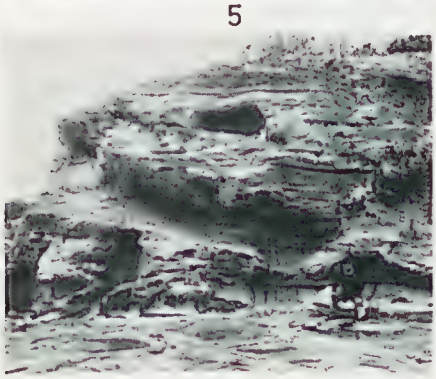

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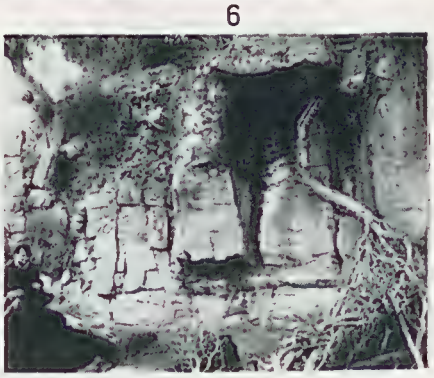

8

A NEW GENUS IN THE HOLOTHURIAN FAMILY SYNAPTIDAE, WITH A NEW SPECIES FROM TASMANIA

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(With 15 figures.)

(Communicated by Dr. W. Bryden)

Late in 1964, one of us (D.L.P.) received from Professor V. V. Hickman in Tasmania a specimen of a new synaptid holothurian from that island. Professor Hickman had prepared permanent mounts of representative calcareous deposits of the specimen, and very kindly offered all of his material of the species to D.L.P. for inclusion in a report on the apodous holothurians of the Australian Museum which was then in preparation. Early in 1966 F.W.E.R. received from the Oslo Museum six specimens and a fragment of the same species. Quite by accident we discovered that we were in the process of describing this new species independently. This joint contribution comprises the sum total of our investigations.

We would like to thank Professor V. V. Hickman for making the holotype available to D.L.P., and Dr. T. Soot-Ryen for giving F.W.E.R. the opportunity of examining specimens from the Oslo Museum. We are grateful to Miss Ailsa M. Clark of the British Museum (Natural History) for her help and encouragement during the preparation of certain parts of this paper.

The distinctive characters of the new species from Tasmania and some other species formerly referred to the genus *Protankyra* Oestergren, 1898 led F.W.E.R. to the suggestion that the genus *Protankyra sensu lato* comprises two discrete groups of species. One group, which includes the type species of the genus, has oval to circular anchor plates with many perforations while the other, which includes the new species described here, has anchor plates which are more or less elongated and have few perforations. This latter group is here referred to a new genus which, for the reasons given below, seem to be intermediate between *Protankyra* restricted and *Labidoplax* Oestergren, 1898. The new genus embraces all of the species found in group D of the key given by H. L. Clark (1907; 98) together with some others described or redescribed since the publication of Clark's key. For the purposes of convenience a key to the species referred to the new genus is given below.

Order APODIDA Brandt, 1835
Family Synaptidae Burmeister, 1837
Rynkatorpa n.g.

....*Diagnosis*: Tentacles 12. Anchors and anchor plates all of one kind, but varying in size. Anchors not conspicuously asymmetrical. Anchor plates more or less elongate and irregular in outline, with few (25-50) perforations, of which two near center of plate are usually conspicuously larger than the rest (except in *R. uncinata*). Perforations with smooth or spinous margins. Polian vesicles usually one to three (except in *R. uncinata* which has four to five).

Type-species: *Rynkatorpa hickmani* n. sp.

Also included in the genus: *Synapta challengeri* Theel, 1886; *Protankyra duodactyla* H. L. Clark, 1907; *P. bicornis* Sluiter, 1901; *P. sluiteri* Fisher, 1907 (nom. nov. for *P. sibogae* Sluiter, 1901); *P. timida* Koehler and Vaney, 1905; *P. bisperforata* H. L. Clark, 1938. Whether *Synapta uncinata* Hutton, 1872, should be included in this genus is debatable. It would appear, with its 4-5 polian vesicles and plates which lack the two characteristic large centrally placed perforations, that this species is an intermediate link between the new genus and *Protankyra*.

Etymology: The generic name is of feminine gender, and is an anagram of *Protankyra* into which genus the included species were placed by H. L. Clark, 1907.

Remarks: The new species is selected as the type of this genus in preference to older species because it is now the best-known, and is described here from a good size range of specimens.

This genus seems to be intermediate between *Labidoplax* and *Protankyra* restricted, for in several species the anchor plates approach the condition found in *Labidoplax*, in which latter genus they have a characteristic "handle". *Protankyra* species generally have more Polian vesicles than those in *Rynkatorpa* while species of *Labidoplax* usually have only one Polian vesicle.

Future investigations may show that this new genus can be further subdivided for although *R. uncinata* (Hutton) has all of the diagnostic characters given here for the genus, it differs from

all other species in the genus in possessing 4-5 Polian vesicles, while the rest have 1-3. This character must be treated cautiously, however, for it is well known that the number of Polian vesicles can increase with growth. In possessing two digits on each tentacle *R. duodactyla* (H. L. Clark) and *R. bicornis* (Sluiter) may be distinguished easily from all other species in the genera *Rynkatorpa* and *Protankyra*. The latter species as described by Sluiter (1901; 131, pl. 10 fig. 15) has calcareous deposits which are unique among the synaptids. The anchors (if correctly represented by Sluiter) with grains on the vertex and no serrations on the arms indicate a possible affinity with the genus *Synaptula* Oersted 1849, but the anchor plates are of the type found in *Rynkatorpa*. This species was placed in group D of his key by Clark (1907; 98), and it is included in the key below; a re-examination of the type material of *R. bicornis* should establish with certainty the systematic position of the species.

Key to the species in Rynkatorpa n.g.

1 (4) Tentacles with two digits.

2 (3) Accessory calcareous deposits present as perforated plates up to 0.35 mm. in diameter; one Polian vesicle .... *bicornis* (Sluiter)

3 (2) Accessory calcareous deposits absent; two Polian vesicles *duodactyla* (H. L. Clark)

4 (1) Tentacles with four digits.

5 (6) Anchor stock branched; anchors up to 0.6 mm. long .... *sluiteri* (Fisher)

6 (5) Anchor stock unbranched; anchors usually less than 0.5 mm long.

7 (8) Perforations of anchor plates with slightly spinous margins *timida* (Koehler and Vaney)

8 (7) Perforations of anchor plates with smooth margins.

9 (14) Anchor plates with two central perforations conspicuously larger than the rest.

10 (13) Anchor plate with rudimentary bridge and with posterior end often narrowed to form a rudimentary "handle"; one or two Polian vesicles.

11 (12) Anchors 0.24-0.35 mm long, anchor plates 0.20-0.27 mm long; two Polian vesicles *challengeri* (Theel)

12 (11) Anchors 0.09-0.23 mm long, anchor plates 0.09-0.17 mm long; one Polian vesicle *hickmani* n. sp.

13 (10) Anchor plate without a rudimentary bridge or "handle"; three Polian vesicles .... *bisperforata* (H. L. Clark)

14 (9) Anchor plates with perforations of varying size; no two central perforations consistently and conspicuously larger than the rest .... *uncinata* (Hutton)

(Note: F.W.E.R. examined the type specimens of the species *Synapta challengeri* Theel, 1886, and found that the perforations of the anchor plates were perfectly smooth, as Theel (1886) represented them. This character is regarded as diagnostic in the key above. If the illustration given by Koehler and Vaney (1905, pl. XV, figs. 33-35) of the anchor plate of their *Protankyra timida* is accurate then it would appear that *P. timida*, formerly regarded as a synonym of *S. challengeri*, is a valid species, distinguishable from *S. challengeri* on the basis of the spinous margins of its anchor plate perforations).

Rynkatorpa hickmani n. sp.
(Fig. 1-15)

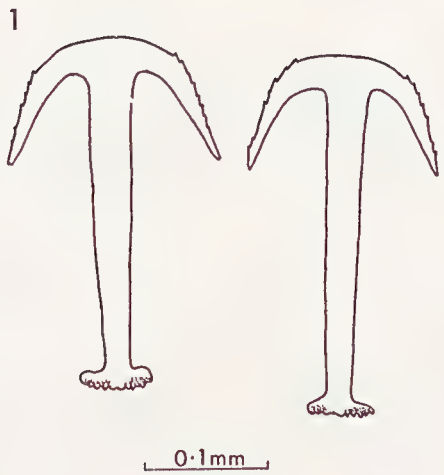
Diagnosis: Tentacles with four digits. Anchors 0.09-0.23 mm long, stock unbranched. Anchor plates 0.09-0.17 mm long, with two central perforations conspicuously larger than the rest; plates with rudimentary bridge and with posterior end narrowed to form a rudimentary "handle". One Polian vesicle.

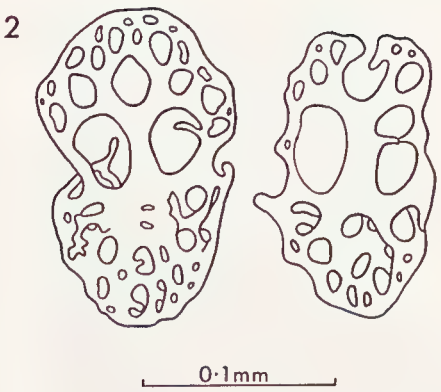
Description of Holotype: Specimen in two pieces, anterior portion 30 mm long, posterior portion 70 mm long. Diameter of body about 7 mm. Skin thin, translucent. Tentacles twelve, decreasing in length from dorsal to ventral side, median ventral pair being shortest. Tentacle stem terminates distally in small conical knob. On each side of knob are two slender digits, of which outer pair are larger. Numerous sensory cups on each side of basal half of oral surface of tentacles.

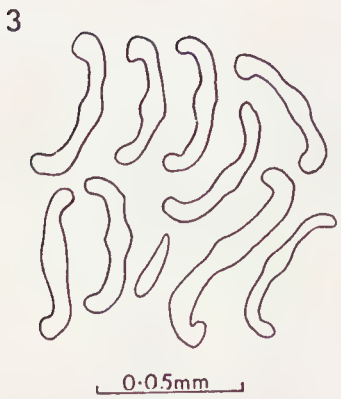
Anterior and posterior regions of body with markedly different calcareous deposits. Anterior anchors and plates smaller and less numerous than posterior anchors and plates. Anchors from anterior end 0.135-0.159 mm long, average length 0.144 mm; width across arms 0.095-0.108 mm, average width 0.100 mm. Arms with two to three teeth or occasionally none. Stock of anchor unbranched, with coarse denticulations (Fig. 5). Anchors associated with anchor plates, the latter often incomplete or in process of formation; many anchors without plates. Complete plates with two large angular perforations. In front of these are several smaller perforations of which central one is largest. Behind two large central perforations are numerous smaller holes and some projections which form rudimentary bridge for support of anchor (Fig. 2). Anterior anchor plates 0.132-0.153 mm long, average length 0.142 mm and 0.084-0.100 mm broad, average breadth 0.091 mm. In posterior region of body anchors 0.147-0.226 mm long, average length 0.200 mm, and 0.111-0.150 mm wide, average width 0.129 mm. Arms with two to seven teeth (Fig. 1). Anchor plates 0.137-0.168 mm long, average length 0.153 mm and 0.095-0.111 mm broad, average breadth 0.101 mm. Plates in various stages of development (Fig. 4). Complete plates have fewer perforations in front of large central perforations than those from anterior end of body.

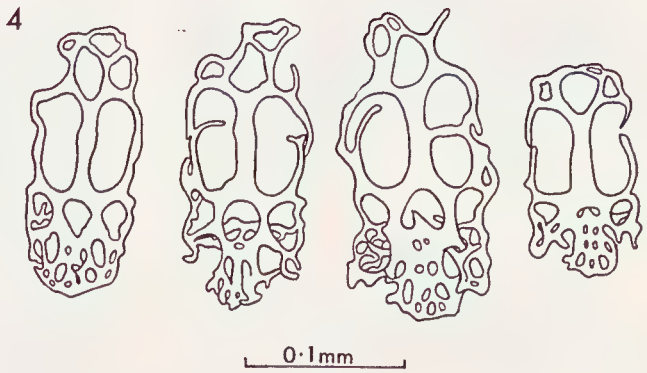
Anterior body wall with numerous curved or straight accessory rods approximately 0.050 mm in length, swollen near middle; some with swollen or branched extremities. Associated with rods are small plates with one to four perforations (Fig. 7). In body wall above radial muscles themselves are numerous miliary granules (Fig. 6). In muscles granules arranged into two densely packed rows, but also scattered between rows. Accessory rods and plates, miliary granules, found only in anterior body wall.

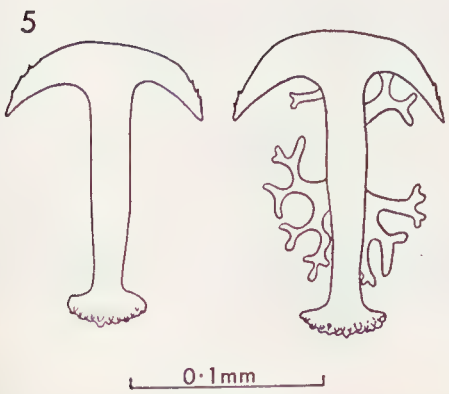
Tentacles with curved and straight rods averaging 0.045 mm in length (Fig. 3). Toward base of

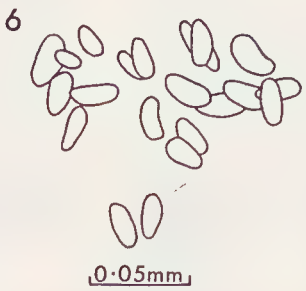




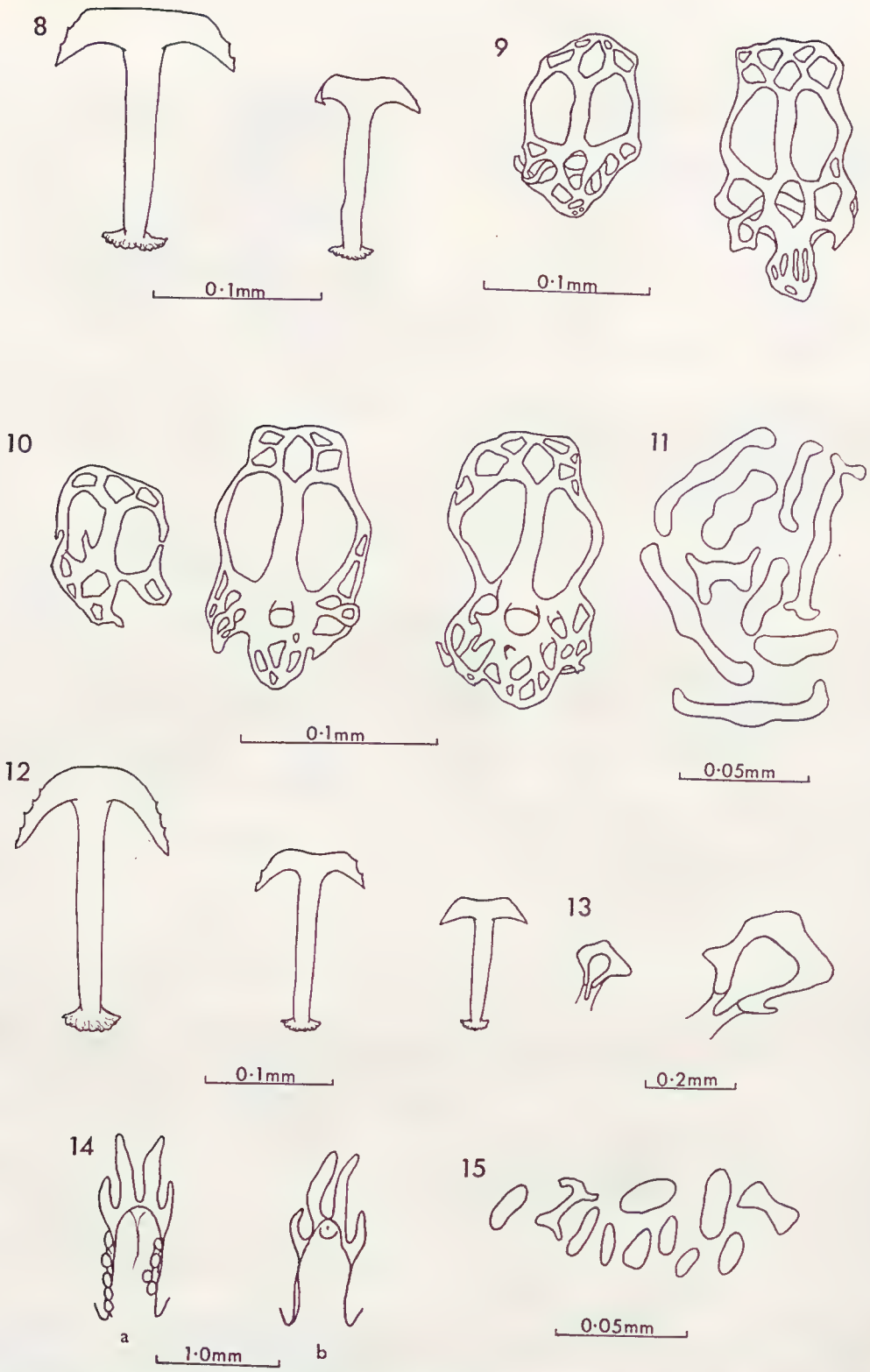








FIGS. 1-7.—*Rynkatorpa hickmani* n. sp. Holotype. Fig. 1, anchors from posterior body wall; fig. 2, anchor plates from anterior body wall; fig. 3, tentacle deposits; fig. 4, anchor plates from posterior body wall; fig. 5, anchors from anterior body wall (one with associated developing plate); fig. 6, miliary granules from radial muscles; fig. 7, accessory rods and plates.



FIGS. 8-15.—*Rynkatorpa hickmani* n. sp. Paratypes. Fig. 8, anchors from anterior body wall; fig. 9, anchor plates from posterior body wall; fig. 10, anchor plates from anterior body wall; fig. 11, tentacle deposits; fig. 12, anchors from posterior body wall; fig. 13, ciliated funnels; fig. 14, tentacles—a, inner (oral) aspect, b, outer aspect; fig. 15, miliary granules from radial muscles.

tentacle rods become shorter, thicker, resembling miliary granules.

Description of Paratypes: Most expanded specimen (on which description mainly based) 27 mm long. Other specimens contracted, with bulbous anterior end and posterior "tail". Total length ranges from 10-25 mm. One fragment (anterior end only) also present. Radial muscles and intestinal tract visible through transparent skin. Twelve tentacles each with four digits and four to seven sensory cups on each side of oral surface (Fig. 14a, 14b). Two ventral tentacles smallest, adjacent one on each side slightly longer, remainder longest but these latter of equal length. "C"-shaped rods and small granules present in tentacles (Fig. 11). Twelve eye spots present on disc.

Calcareous ring small, stout, with three ventral radial plates each with a perforation (as in Heding, 1928; 249, fig. 45, 12 & 13). Polian vesicle single; stone canal single but with three branches. Intestine not looped but attached along its length to body wall by membranous dorsal mesentary. No gonads found. Ciliated funnels (Fig. 13) present only along mid-line of left dorso-lateral inter-radius.

Calcareous deposits in anterior part of body slightly smaller than those in posterior region. Anchors and plates in both areas vary in size. Posterior anchors 0.2 x 0.12 mm (length x breadth), 0.13 x 0.08 mm, and 0.10 x 0.06 mm (Fig. 12). Anterior anchors 0.13 x 0.09 mm and 0.09 x 0.05 mm (Fig. 8). Larger anchors usually with four small teeth on each arm; arms of smaller anchors faintly dentate, generally with only two small teeth. Shaft smooth, stock unbranched but with coarse denticulations. Anchor plates posteriorly 0.10 x 0.07 mm (length x breadth) and 0.16 x 0.09 mm (Fig. 9); anteriorly 0.14 x 0.09 mm, 0.10 x 0.07 mm, and 0.09 x 0.07 mm (Fig. 10). Plates approximately rectangular, with two large centrally placed ovoid to reniform perforations. At distal end of plate are many small holes which may extend into a short reduced "handle". Some twisting of plate also occurs here, forming a weak bridge. Proximal part of plate with five to six regularly arranged angular perforations. Usually middle perforation slightly larger than those lying on each side of it. All perforations with smooth margins. Miliary granules present in anterior end of body; shape ovoid, length 0.01-0.03 mm (Fig. 15). No small quadrilocular plates.

Holotype: Australian Museum, Sydney. Derwent Estuary, Tasmania. Dredged by Dr. E. R. Guiler, 18th April, 1963, depth ca. 7 fathoms; mud, sand and grit.

Paratypes: Burnie Harbour, N.W. Tasmania, collected by Vigeland, 30th May 1959. Six specimens and a fragment. Deposited at the Zoological Museum, Oslo.

Growth changes: Some changes in the calcareous deposits occur with growth of this species. The holotype has larger anchors and plates than the paratypes. In the posterior end of the body the anchors of the holotype tend to have a larger number of serrations on the flukes and the anchor plates tend to be more irregular in shape. Accessory calcareous deposits are numerous in the anterior end of the holotype but were not found in the paratypes. It is of some interest that the largest paratype of total length 27 mm had no trace of gonads. This species must attain a considerable size before reaching sexual maturity.

Remarks: The species is named in honour of Professor V. V. Hickman, Professor Emeritus of Zoology, University of Tasmania, who has contributed so much to our knowledge of the holothurians of Tasmania. It is the second synaptid recorded from Tasmania. *Leptosynapta dolabrifera* (Stimpson) was found there by H. L. Clark (1938) and again by Hickman (1962).

Rynkatorpa hickmani may readily be distinguished from its congeners on the basis of the distinctive characters shown in the key above. Its closest relative seems to be *R. challengeri* (Theel) which is so far known from the East Indies, Fiji, and Hawaii in depth of 252-1788 m (H. L. Clark, 1907; 100). *R. bisperforata* (Clark), which occurs at Broome, Western Australia, has anchor plates of a different type from those of *R. hickmani*.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 101.

NOTES ON THE DETERMINATION OF SHORTENING BY FLEXURE FOLDING MODIFIED BY FLATTENING

By

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(With six text figures.)

ABSTRACT

A simple visual field method of determining the amount of flattening of a flattened flexure fold is described. The method allows estimation of the pre-flattening thicknesses and dips of the deformed beds, so that original thicknesses of sequences and the total shortening of the layers by folding may be calculated.

INTRODUCTION

Van Hise (1894) recognised two fundamental groups of folds—the flexure (also known as parallel or concentric) type and the similar folds. The geometrical characters of the two groups differ markedly. With flexure folds the thicknesses of the beds measured at right angles to the bedding surfaces remain constant throughout the fold, whereas with similar folds the thicknesses of the beds measured parallel to the axial surface to the fold are constant but thicknesses measured perpendicular to bedding are variable (fig. 1).

In general, it appears that folds usually encountered in the field are of a flexure type modified by flattening, which when extensive results in folds that superficially resemble those of similar type (de Sitter, 1958; Ramsay, 1962). Only flattened flexure folds are considered in these notes.

Flattened flexure folds are usually readily distinguished especially where variations in the thickness of some layers are significantly less than adjacent ones. Again, acutely pinched lower boundaries of beds are characteristic of this type of fold (fig. 2). Where doubt exists as to whether the examined fold is of the type considered here, marked variations in thicknesses of beds measured parallel to the axial plane of the fold are diagnostic (see Ramsay, 1962).

In the following geometrical analysis it is assumed that layers were initially of uniform thickness. Deformation is divided into two distinct types—flattening and pure flexure folding—for geometrical analysis only. In the actual fold development parts may be undergoing flexure folding whilst other parts are being flattened (Williams, 1965).

ESTIMATION OF FLATTENING

Ramsay (1962, p. 314-15) has presented a graphical method whereby the percentage of flattening of a flexure fold may be determined. The method involves the comparison of thicknesses measured perpendicular to bedding of a competent horizon of known dips with the thickness of that bed at the fold hinge. However, where difficulties are encountered in measuring with sufficient accuracy thicknesses of competent horizons, due perhaps

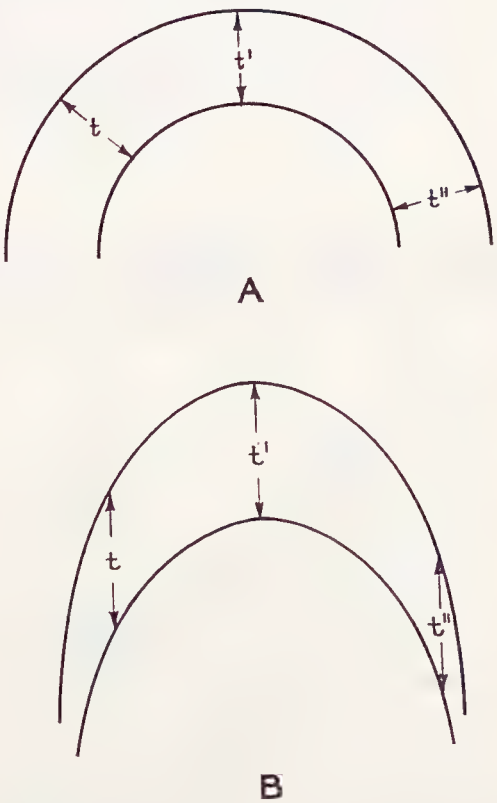

FIG. 1

A. Profile of flexure fold illustrating uniform thickness of layer normal to bedding. $t = t' = t''$.

B. Profile of similar fold with uniform thickness of layer measured parallel to axial surface. $t = t' = t''$.

to well developed sole markings or tectonically frayed boundaries, Ramsay's graphical method is unsatisfactory. Furthermore, with folds exhibiting differential flattening Ramsay's method is uncertain, for this phenomenon may be attributed to inaccurate field measurements.

In order to determine the shortening of strata by folding an estimation of the amount of flattening in a fold is of use only if the form of the profile of the pre-flattened fold is known. Therefore, in using Ramsay's method it is necessary to reconstruct the original fold profile by trial and error before any further calculations can be made.

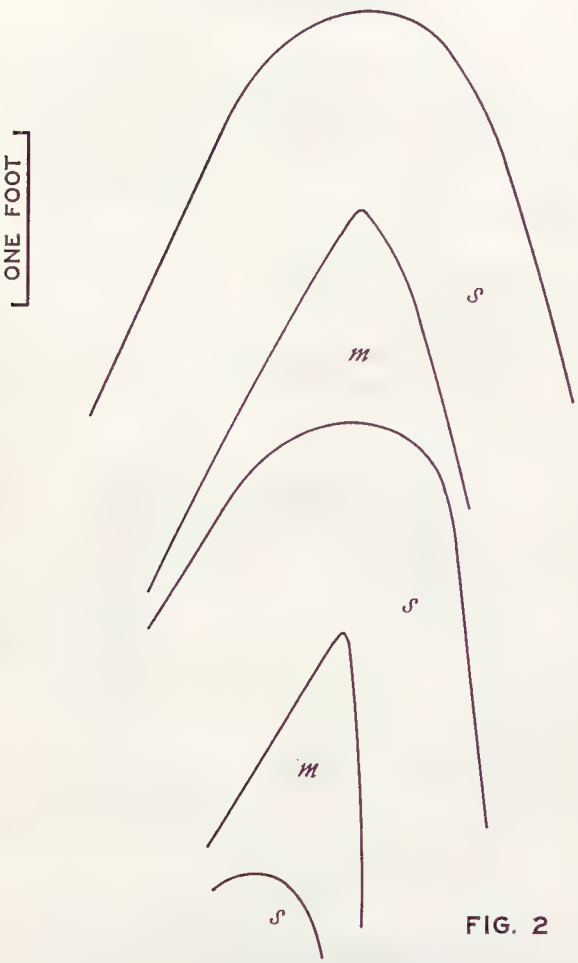

FIG. 2

Profile of flattened flexure fold of sandstone (*S*) and interbedded mudstone (*M*). Location near Tullochgorum on the South Esk Highway, North-East Tasmania. Field orientation: fold axes plunge 28° in direction 145°, axial surface dips approximately 56° in direction 205°.

Note marked difference in competence of sandstone and mudstone, and acute pinch at lower boundaries of sandstone.

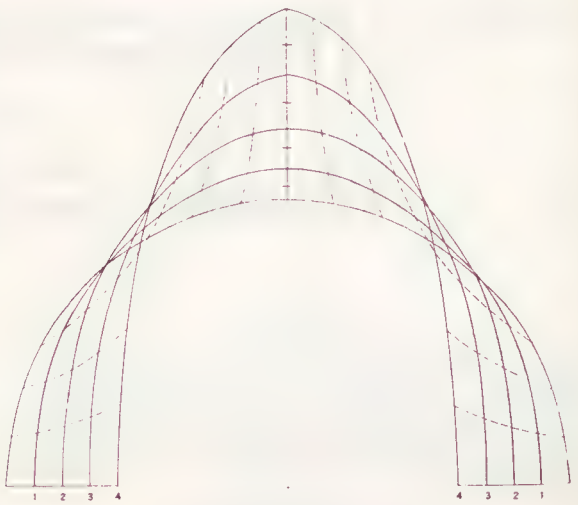

FIG. 3

Semi-circular area flattened by 10, 20, 30 and 40 per cent. Corresponding points on the curves are indicated by broken line. See text for further explanation.

In the writer's experience pre-flattened fold profiles correspond to arcs of circles, and this appears to be the experience of many others in that it is the underlying assumption of the treatment given to flexure folds in text-books (e.g., de Sitter, 1964) and in Ramsay's paper. Nevertheless, it is considered necessary that in any method used in the calculation of shortening by folding, pre-flattened fold profiles which do not correspond to arcs of circles are immediately recognised, for in such cases the calculation of shortening is unique for each fold and they are therefore not considered in this paper.

During routine mapping activities it appears advisable to use methods for determining flattening in folds which do not depend on numerous accurate measurements of the thicknesses of layers, find no difficulties with differential flattening and give an immediate indication as to whether the pre-flattened fold profile is of an arc of a circle. With these points in mind simple graphs, based directly on the theoretical consideration of de Sitter (1958), have been constructed for visual comparison with the folds encountered.

Figure 3 shows an area bounded by a semi-circle flattened by 10, 20, 30 and 40 per cent. Corresponding points on the curves are indicated by a broken line. The figure, with a semi-circle of three inches radius, is engraved on a perspex sheet of 1/12th inch thickness. This sheet is used in the field by holding, preferably mounted on a light tripod, at a suitable distance between eye and outcrop perpendicular to the direction of the fold axis. The distance between eye and perspex sheet is varied until the fold profile fits the set of engraved curves. Quicker results are obtained when the method is used with folds in layers showing acute pinches at a boundary surface so that the approxi-

mate centres of folding during the flexural deformation are known. By comparing the fold profile with the set of engraved curves on which corresponding points have been superimposed the pre-flattened dips of the sectors of the fold can be readily determined. Figure 4A illustrates the use of this method.

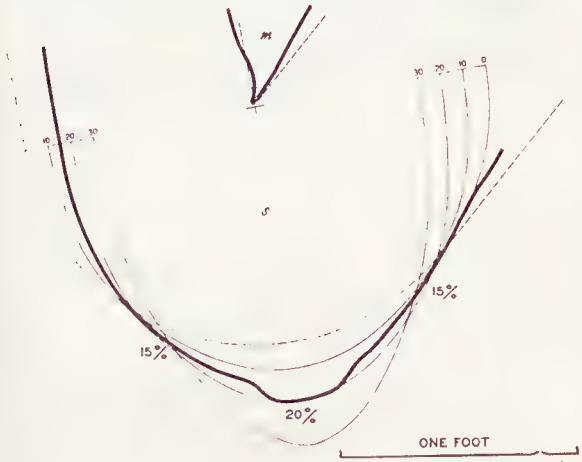

FIG. 4A

A. Profile (thick line) of syncline in sandstone (*S*) with amounts of flattening determined by superimposed graph (thin line) shown on outer arc. Broken line indicates unflattened fold profile. Location near Tullochgorum, on South Esk Highway, North-East Tasmania. Field orientation: fold axis plunge 14° in direction 125°, axial surface dips approximately 61° in direction 200°.

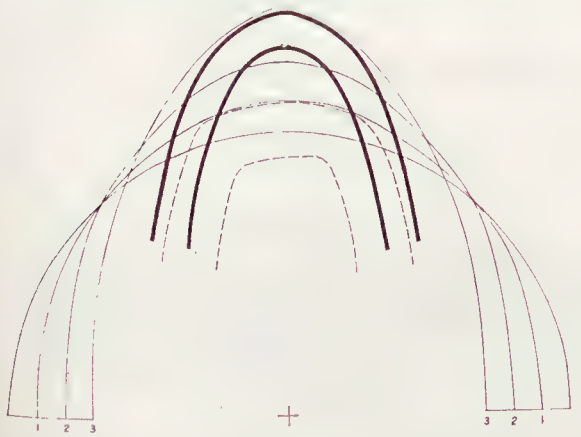

FIG. 4B

B. Misfit folds (thick and broken lines) indicating pre-flattened fold forms are not of arcs of a circle.

Misfitting fold profiles (fig. 4B) and differences in the percentage flattening determined by comparing both upper and lower surfaces of a bed with the curves inscribed on a perspex sheet, indicate that the pre-flattening fold profiles are not of a circular arc. *It must be emphasised that pre-flattened fold forms which are not of an arc of a circle are readily recognised by using the method described.*

Having determined the percentage of flattening of a fold of a pre-flattened profile of an arc of a circle, it remains to determine the amount of shortening by pure flexure folding.

ESTIMATION OF SHORTENING BY FLEXURE FOLDING

For simplicity let the angle of the arc of uniform curvature be the same in both anticline and adjacent syncline, and let the limbs be straight. Then in fig. 5, where the radius of curvature of the hinges is greater or equal to the thickness of the competent unit folded, it is evident that the percentage shortening is—

$$\frac{l\left(1-\cos\alpha\right)+\left(r_1+r_2\right)\left(\frac{\pi\alpha}{180}-\sin\alpha\right)}{l+\frac{\pi\alpha}{180}\left(r_1+r_2\right)}\cdot 100 \quad \ldots\ldots\ldots (1)$$

where l is the length of the fold limb, α half the angle of uniform curvature, r_1 the radius of curvature of the synclinal arc and r_2 the radius of curvature of the anticlinal arc.

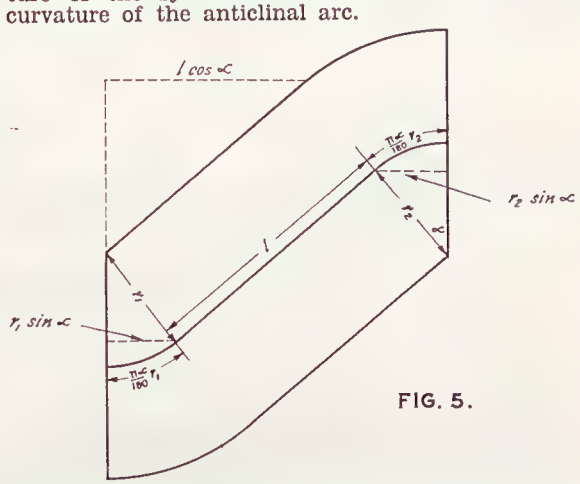

FIG. 5.

Geometry of profile of flexure fold of competent unit where α is half angle of uniform curvature, r_1 radius of curvature of synclinal arc, r_2 radius of anticlinal arc, and l length of fold limb.

In the special case of simple flexure folding, where arcs are of constant curvature (fig. 6) and l is zero, the percentage shortening is—

$$\left(1-\frac{180\sin\alpha}{\pi\alpha}\right)\cdot 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In simple flexure folding, shortening is constant for each value of α, and when centres are colinear is approximately 36.6% (fig. 6B), which is the amount often incorrectly quoted for the maximum amount of shortening by flexure folding (see Ramsay, 1962, p. 313), for in the more general cases it is evident by inspection of equation (1) that considerably more shortening can occur.

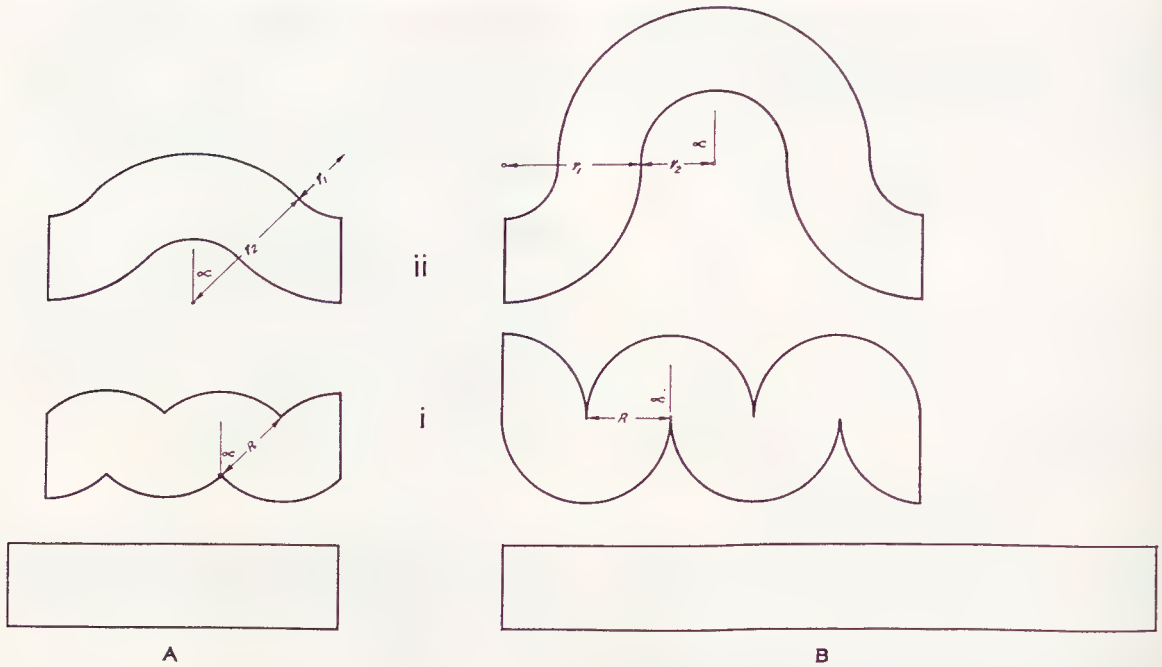

FIG. 6

Geometry of profiles of simple flexure folds of competent units for varying values of α, half angle of uniform curvature, and R, distance between centres of curvature. Shortening in A is 10% and B 36.6%.
(i) R = thickness of layer.
(ii) $R >$ thickness of layer.
Note $R = r_1 + r_2$, where r_1 is radius of curvature of synclinal arc, and r_2 radius of anticlinal arc.

ESTIMATION OF TOTAL SHORTENING

If the shortening by pure flexure folding is X% and by flattening Y%, then the total shortening is—

$$\left(X + Y - \frac{XY}{100}\right)\ \% \qquad (3)$$

With accordian or concertina folds of long straight limbs it is essential to study the hinges in order to determine the amount of flattening (see Williams, 1965). However, the folds may be neglected in the final calculations of shortening. Using the visual comparison method both the flattening percentage and the pre-flattened dip of the limbs can be determined (fig. 4A), and the total shortening is given by—

$$\left[1 - \left(1 - \frac{X}{100}\right)\cos\alpha\right] . l . 100\% \qquad (4)$$

where X is the percentage flattening, α the dip of the pre-flattened limb and l the length.

CONCLUSIONS

Usually folds encountered in the field are of a flattened flexure type which when unflattened have profiles of arcs of circles. The visual graphical method described above is constructed to analyse these folds, but it is designed so as to allow immediate recognition of a fold with a pre-flattened profile of curves not of arcs of circles in the event of one being encountered.

A comparison of fold profiles in the field with a set of curves representing various percentages of flattening of a semi-circular area inscribed on a perspex sheet, allows a calculation to be made of not only the original thicknesses of the deformed layers but also the horizontal extent of the beds before folding. Determinations such as these will give true variations in stratigraphic thicknesses from one locality to another and greatly help in building up a picture of the amounts of structural deformation in regions.

ACKNOWLEDGMENTS

The methods described have been available for use in the Geological Survey since early 1964. This account has benefited much from discussions with Mr. R. D. Gee and Mr. D. Leaman. I thank Mr. I. B. Jennings, Mr. G. Everard, Mr. R. D. Gee, Mr. D. Leaman and Mr. P. Legge for reading and commenting on the manuscript. I also wish to record my gratitude for discussion of the subject-matter of this paper when it was presented in a seminar in the Geology Department, University of Tasmania, in July, 1966.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 101.

SECONDARY MAGNETIZATION OF SOME PALAEOZOIC ROCKS FROM TASMANIA

by

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(Communicated by Dr. W. Bryden.)

(With four text figures.)

ABSTRACT

A variety of igneous, sedimentary and metamorphic Palaeozoic rocks from Tasmania have similar directions of NRM—steeply upward. Although the mean direction is not significantly different at the 95% confidence level from the present field, its inclination is slightly steeper. Moreover, the palaeomagnetic pole calculated from these directions is closer to Tertiary poles from Australia than to the present pole. On this data it is statistically more probable that the NRMs are of Tertiary rather than recent age. Their characteristics are the same as viscous PTRMs, and they are likely to have been acquired during a period of slightly elevated rock temperatures. This warming-up may have been associated with Tertiary basaltic activity in Tasmania, or with slightly later regional heating over wide areas of eastern Australia, which has previously been suggested on petrological grounds.

1. INTRODUCTION

Although a considerable amount of palaeomagnetic work has been carried out in Carboniferous and younger rocks in Australia, the only published data on pre-Carboniferous rocks from Australia are those of Irving and Green (1958) and Green (1961) who studied small collections of sediments and igneous rocks of Proterozoic, Cambrian and Siluro-Devonian age, and of Briden (1966) concerning the NRM in a single, small igneous body of late Silurian age which had been the subject of preliminary work by Green. In these studies, evidence was presented which suggested that the NRMs which had been measured were primary (same age as the host rocks) and hence gave information on the geomagnetic field at the time when the rocks were formed.

In the present study, results are described from a variety of igneous, sedimentary and metamorphic rocks of pre-Carboniferous age in Tasmania (particularly from the Cambrian and Devonian of North-Western Tasmania). The NRMs of most of the rocks studied are likely to be secondary (younger than their host rock), and evidence is presented in support of the view that the probable age of the NRMs is early Tertiary, and that they were acquired during a period of slightly elevated rock temperature and were stabilised by cooling to near present-day temperatures. Experimental tests of the physical plausibility of this hypothesis have been described elsewhere (Briden 1965).

Between 1 and 10 oriented rock *samples* were collected at each *site* and 2 *specimens* were cut from each sample. Most of the results are of measurement of total NRM, but certain samples were selected for alternating field or thermal demagnetization with a view to testing the stability of remanence. Directions of NRM in individual specimens may be represented as unit vectors at a point; the resultant R_N of N vectors at a site is a measure of precision. Those site mean directions which are shown to be significant at the 95% confidence level (Watson, 1956) are then represented by unit vectors in calculating the mean direction of NRM for the group of rocks. The resultant (R) of the site mean vectors is related to the estimate (k) of between-site precision by the equation

$$k = \frac{B - 1}{B - R} \quad \text{(Fisher, 1953)}$$

where B is the number of sites. The palaeomagnetic pole (ϕ, λ) was calculated on the assumption of a geocentric dipole configuration of the geomagnetic field at the time when rocks were magnetized.

2. RESULTS

Pre-Cambrian at Burnie, Tasmania

On the coast between Burnie and Cooee (Figure 1) the Cooee Dolerites invade the Burnie Slate and Quartzite Formation (Spry, 1957). One sample of dolerite was dated radiometrically by Richards (in Spry and Banks, 1962) at 700 m.y. Three oriented samples from the dolerite sills and four from the intervening grey quartzite were very weakly magnetized (intensities less than 10^{-6} gauss) and only one specimen of quartzite contained detectable NRM. Directions in the dolerite were steeply upward, but no analysis can be made on the basis of measurement of three specimens from only two samples (the third having no detectable remanence), and no further work seemed justified.

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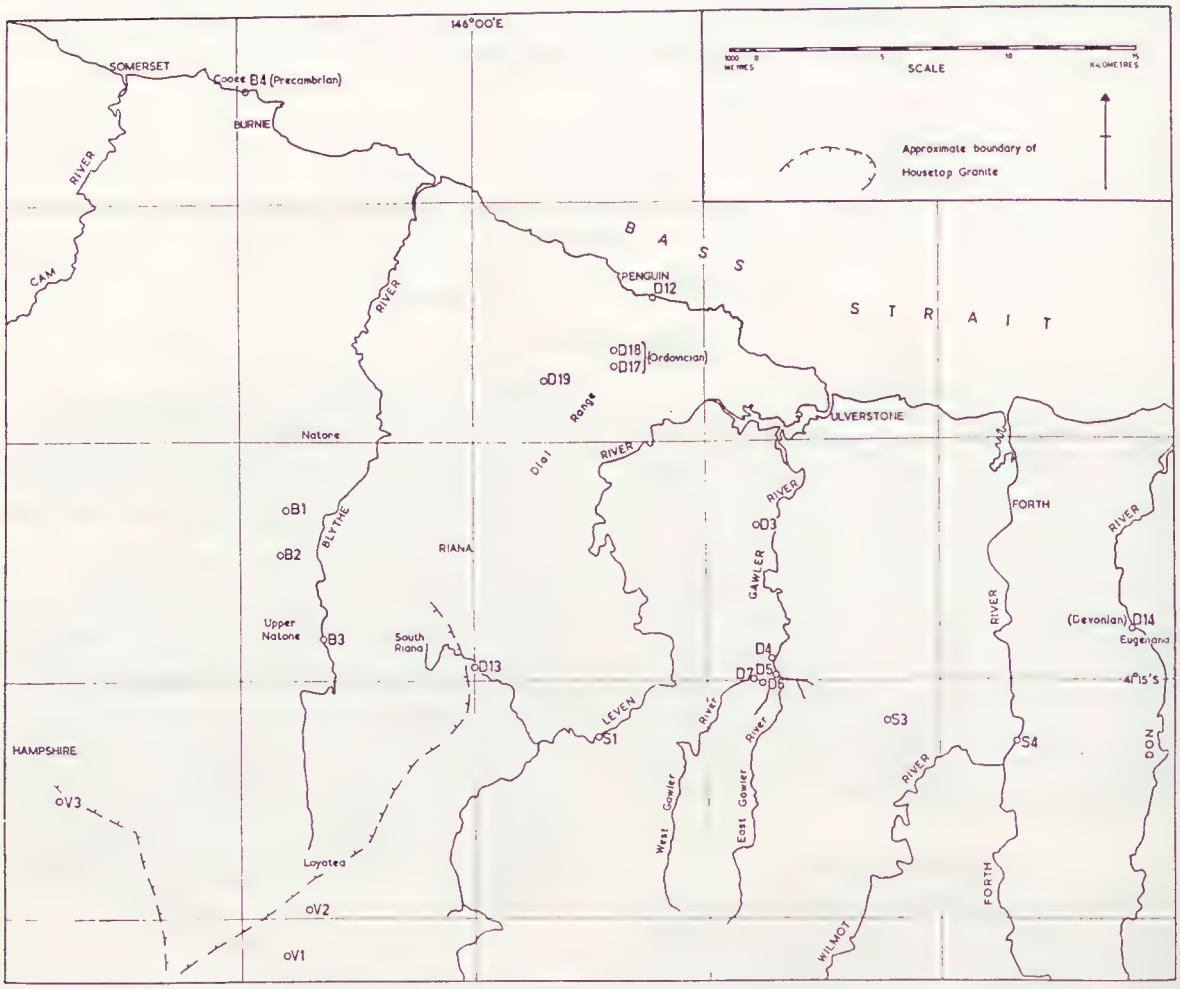


FIGURE 1.—Palaeomagnetic sampling sites in the Penguin district, northwestern Tasmania. The map is based on topographic (Lands and Surveys Dept., Tasmania), soils map (C.S.I.R.O.) and aerial photographs (Division of National Mapping, Dept. of National Development, Canberra). For rock types see Tables 1 to 3.

Cambrian, North-Western Tasmania

From a structurally complex trough of Cambrian rocks south of Penguin, mudstones and sandstones, trachytic lavas and tuffs, hornfels, a syenite boss and a reef of hematite ore, all of Middle and Upper Cambrian age (Burns, personal communication), were sampled (Figure 1). Six samples of red-brown sandstones were collected from a 700 m. section near Stony Point, Montagu, which was correlated on lithological grounds with the Dundas Group (Middle and Upper Cambrian) by Gulline (1959). Twelve of the site means are significant (Table 1) and all are directed steeply upward relative to the present horizontal. "Correction" for folding is made by "unwinding" folds about their axes, on the assumption that all folding is purely rotational about horizontal axes. Where field evidence indicates more than one period of folding about different axes, correction is made by successively unwinding the folds in order of increasing age. The dispersion of site mean directions is increased by "correction" for folding. Although this may in part be due to the inadequacy of the assumptions about folding, it remains evident that the NRM is independent of the dip of individual beds, which suggests that NRM is younger than the folding (Graham, 1959).

Intensities are variable. Hornfelses at sites V1 and V2 differed in mean intensity by a factor 27. In hematite from the vertical reef, intensity ranged from below the measuring limit of the magnetometer (about 10^{-7} gauss) to nearly 10^{-4} gauss. In trachyte at Paloona Bridge (sites S4A and B) the range was 50 to 370 (x 10^{-6} gauss), and in mudstones at D7 mean intensities in four samples were 8.6, 19.7, 4426.0 and 35.7 (x 10^{-6} gauss) respectively. Intensities at other sites were in the range 10^{-5} to 10^{-6} gauss.

TABLE 1

Site mean directions of NRM in Cambrian sediments and volcanics northwest Tasmania.

Site	Rock Type	S	N	R_N	uncorrected D	uncorrected I	corrected D	corrected I
V1	Hornfelsed tuff	2	4	3.96	32	—73	178	—79
V2	Hornfelsed tuff	6	12	11.42	12	—75	104	—70
D19	Hematite ore	3	6	1.18	....	....	....	....
D3	Acid tuff	5	10	8.52	334	—80	3	—42
D4	Trachyte	5	10	9.02	116	—78	87	—18
D5	Tuff	3	6	5.39	323	—58	281	—36
D6	Tuff	1	2	1.98	341	—48	29	—42
D7	Mudstone	4	8	7.79	71	—75	99	—46
D12A	Spilite lava	1	2	2.00	356	—53	356	—53
S1	Acid tuff	1	1	1.00	73	—60	62	—18
S3	Spilite lava	2	4	2.60	....	....	....	....
S4A	Trachyte	3	6	4.40	130	—87	201	—65
S4B	Trachyte	4	8	3.80	....	....	....	....
S4C	Chert & Sandstone	4	8	7.20	285	—88	63	—15
Stony	Point Sandstones	6	12	10.10	342	—81	290	—60

	B	D	I	k	a	pole ϕ	pole λ
Uncorrected	12	9	—77	18	10.5	45W	66N
Corrected	12	47	—66	3	27.7	97W	57N

N = Number of specimens. S = Number of samples. B = Number of significant sites. R_N = resultant of N unit vectors (see section 1 of text). D = Declination (degrees E of true N). I = Inclination (degrees, downward positive). k = between-site precision. a = semi-angle of 95% cone of confidence.

TABLE 2

Site mean directions of NRM in Ordovician sandstones from Tasmania

Notation as for Table 1.

Site	S	N	R_N	uncorrected D	uncorrected I	corrected D	corrected I
D17	3	6	5.97	337	—78	106	—68
D18	3	6	5.98	1	—71	11	—69
Tim Shea	10	19	14.85	25	—65	121	—75

	N	D	I	k	a	pole ϕ	pole λ
Uncorrected	31	14	—70	6.7	10.8	66W	75N
Corrected	31	95	—77	6.1	11.4	65W	35N

The only Cambrian intrusive rocks which were studied were from a syenite boss on the foreshore at East Penguin (site D9, Figure 1). In nine of the 10 specimens (five samples) inclinations were positive, but the mean was only just significant, at the 95% confidence level, and precision did not improve with alternating field demagnetization. Intensities were in the range 1.5 to 3.5 (x 10^{-6} gauss).

Ordovician Sandstones, Tasmania

In the Penguin district (Figure 1) and at Tim Shea (central Tasmania) sandstones and conglomerates underlie fossiliferous Ordovician limestones and are believed to be of Lower Ordovician age (Spry and Banks, 1962), although those at Tim Shea could possibly be Upper Cambrian (Spry, personal communication). Sixteen samples were collected from sandstones in these sections and NRM in all specimens was directed steeply upward; site mean directions are tabulated in Table 2. Because only 3 sites are distinguished, the precisions before and after correction for folding are compared by analysing specimen directions. These rocks are affected only by the gentle flexuring which is typical of the Tabberabberan (Middle Devonian) progeny in the region. Intensities of NRM were in the range 10^{-5} to 10^{-6} gauss.

Devonian, Northwestern Tasmania

Three samples of Eugenana Beds (cave fillings in Ordovician limestone) had mean direction D = 262°, I = +5° with k = 6, and mean intensity 10^{-6} gauss.

The Housetop Granite was sampled at 3 sites near Natone; in its contact aureole amphibolites of Upper Cambrian mudstones and conglomerates were collected in a creek near South Riana, and a skarn of Ordovician limestone was sampled near Hampshire (Figure 1). Detailed age determina-

TABLE 3

NRM directions in Housetop Granite and its aureole

Notation as for Table 1.

Site	Rock Type	S	N	R_N.	D	I
V3	Skarn	7	14	7.32	93	—75
D13	Amphobolite	5	10	6.42	19	—34
B1	Granite	3	6	5.38	36	—46
B2	Granite	2	4	3.91	348	—82
B3	Granite	7	14	12.87	163	—83

Rock Type	B	D	I	k	a	pole ϕ	pole λ
Granite	3	35	—75	9.7	....	....	....
Thermal metamorphics	2	29	—60	4.6	....	....	....
Granite and aureole combined	5	32	—69	8.6	27.6	86W	66N

TABLE 4

Mean NRM directions from all Tasmanian Palaeozoic rocks described in this paper (except Eugenana Beds and syenite boss, East Penguin)

Notation as for Table 1.

Orientation	No. of Sites	D	I	k	a	pole ϕ	pole λ
Uncorrected	20	17	—74	16.4	8.3	56W	68N
Corrected	20	45	—72	5.6	15.3	79W	58N

tion work by McDougall and Leggo (1965) by both Rubidium-Strontium and Potassium-Argon methods, on several samples including some of those collected for palaeomagnetic purposes, indicates the age of the Housetop Granite to be 375 ± 10 m.y. (Middle Devonian). The mean directions of NRM (Table 3) in the granite and its aureole are not significantly different, and have been combined by the conservative procedure of giving unit weight to each site. The results from Cambrian hornfels at sites V1 and V2 have been analysed with the Cambrian rocks (Table 1); it is possible that they lie within the aureole of the Housetop Granite, and perhaps should be analysed here. However, it will be shown later (Figure 2) that there is no significant difference between directions in Cambrian and Devonian rocks and all will be analysed together (Table 4).

3. CONCLUSIONS.

The only suggestion of primary NRM in the rocks described here is from the Eugenana Beds, and this cannot be discussed in detail because the collection was so small. Insufficient outcrop prevents further study, and there is little prospect of confirming the age of NRM in these beds.

The NRM in Cambrian sediments and volcanics is considered to be younger than the folding because precision is much greater before than after correction for folding. The agreement between directions before correction in these rocks and those in the Ordovician sandstones and the Devonian granite and its aureole—a wide variety of rock types—suggests that they all acquired their NRM at roughly the same time. Accordingly all site means from Palaeozoic rocks from Tasmania (except for the Eugenana Beds and the syenite boss at Penguin) have been combined (Table 4). As before, the precision of grouping of directions relative to the present horizontal and meridian is greater than that after an attempt to correct for folding, and supports the contention that NRM is younger than the folding. Although the mean direction is not significantly different from the present field ($p = 0.05$), its inclination is slightly steeper, and the palaeomagnetic pole position (55W, 68N) is closer to that postulated for Australia during the Lower Tertiary than it is to the present pole—the mean pole calculated by Irving (1964) from several studies of early Tertiary rocks being (50W, 65N).

Although the possibility that the NRMs reported here are of recent origin cannot be ruled out, it is more probable that they are of Tertiary age. Evidence for this is strongest for the Cambrian rocks, for which the circular standard error of the mean NRM direction excludes the present field direction. Thermal demagnetization curves of Cambrian tuff from site D3 and hornfels from site D9 (Figures 3 and 4), are characterised by a broad distribution of blocking temperatures, although this is masked to some extent at D9 by the alterations which are introduced by heating above 300°C. NRMs which have been built up over long period of time at slightly elevated temperatures ('viscous PTRMs') commonly have this same property (Briden, 1965). It is likely that the NRMs in these rocks are viscous PTRMs. It was previously

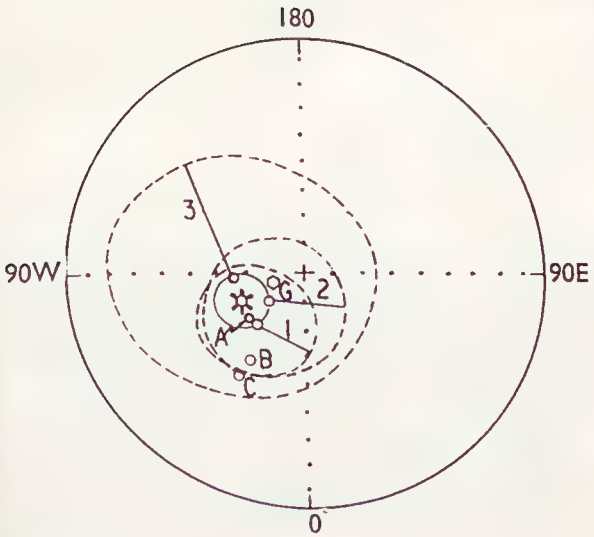
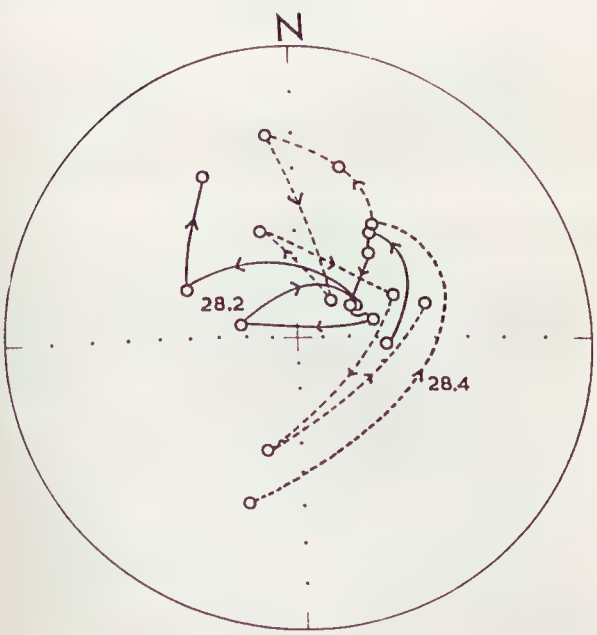


FIGURE 2.—Palaeomagnetic pole positions and approximate ovals or 95% confidence—
1. Cambrian sediments and volcanics.
2. Ordovician sandstone.
3. Devonian granite and aureole.
* Combined Palaeozoic of Tasmania.
C, B, A are the mean Jurassic, Cretaceous and Lower Tertiary poles relative to Australia (Irving, 1964).
G is the geomagnetic pole.
NORTHERN hemisphere equal-area projection.

suggested (Briden, 1964) that they might have been acquired at the time of Tertiary igneous activity in the area, which might have raised the temperature of rocks by a few tens of degrees for a prolonged period. Alternatively, the heating might have been on a regional scale. Hale and Spry (1964) have suggested that regional heating occurred after the basalt extrusion and that it might have reached 200°C in places. It may have been responsible for the occurrence of zeolite facies rocks of many ages (including Tertiary basalts in Tasmania) in various places in eastern Australia. The same regional heating could have given rise to the NRMs which have been detected in the Palaeozoic rocks.

ACKNOWLEDGMENTS

This work was carried out during the tenure of an Australian National University scholarship. I wish to thank Professor E. Irving, formerly of the Department of Geophysics, Australian National University, who suggested the investigation and offered much helpful criticism; the Director and officers of the Tasmanian Department of Mines (especially Dr. K. R. Burns) for their assistance with field work; Professor S. W. Carey and members of staff of the Geology Department, University of Tasmania, for much useful discussion and loan of field equipment; Professor S. K. Runcorn for providing facilities at the Physics Department, University of Newcastle-upon-Tyne, England, during preparation of the manuscript.



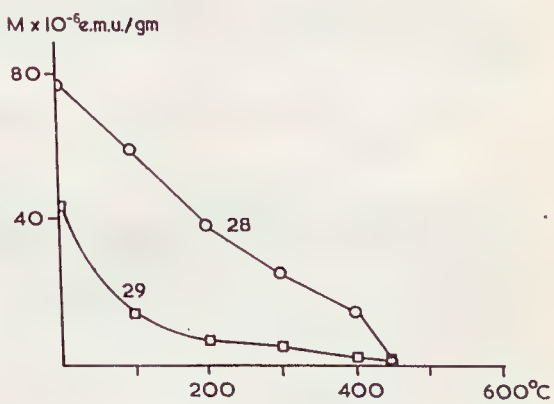


FIGURE 3.—Thermal demagnetization at site D3 in Upper Cambrian tuff. Stereogram shows direction changes in two specimens of CT28. Demagnetization curves show vectorial mean intensities of each of samples CT28, CT29. Intensities are given in e.m.u./gm for comparison with viscous PTRMs (Briden, 1965).

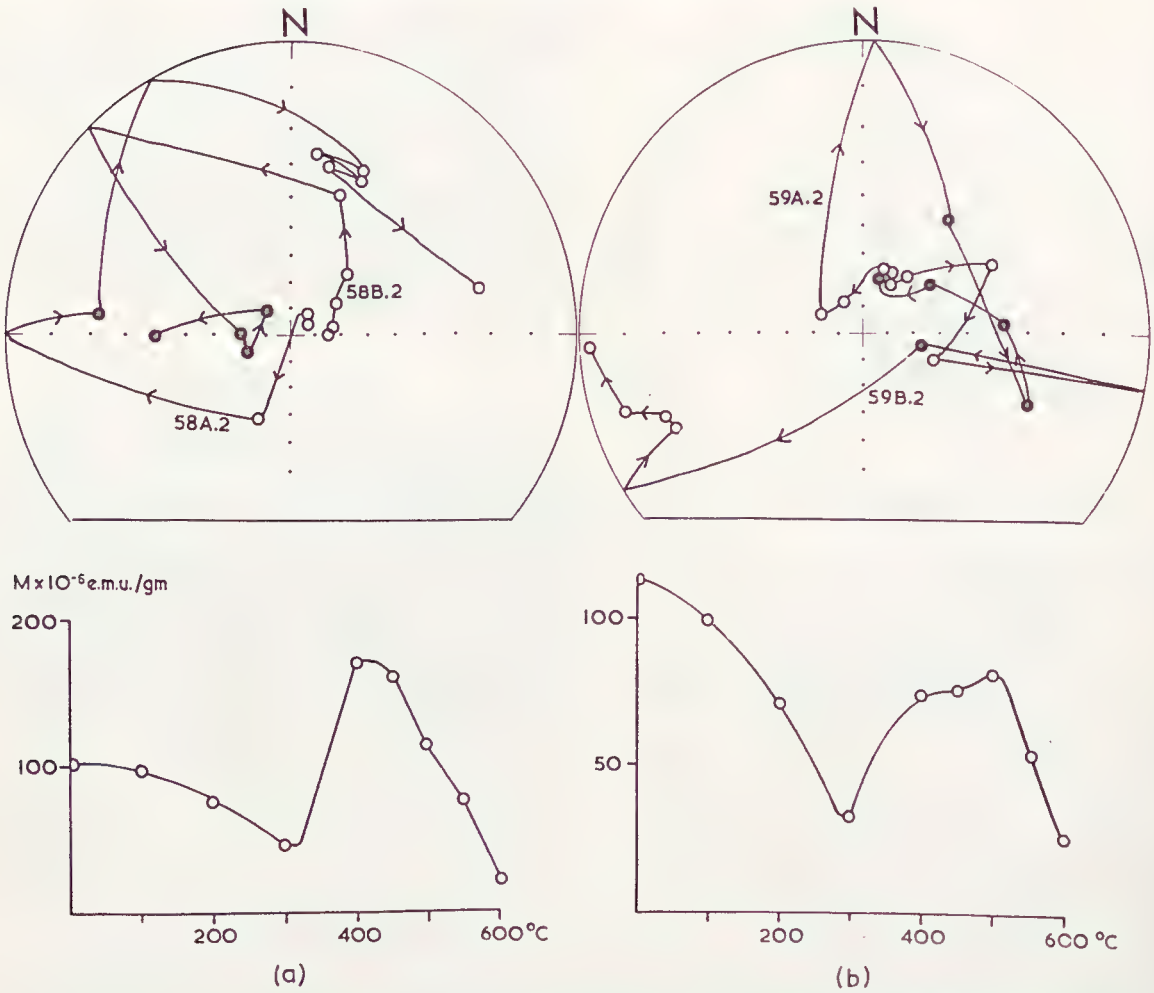


FIGURE 4.—Thermal demagnetization of Cambrian hornfels, site V2. Stereograms and demagnetization curves showing sample-mean intensities (*a*) sample CT58, (*b*) sample CT59.

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SPRENT'S HOBART, circa 1845

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(With nine figures and six plates.)

ABSTRACT

James Sprent's comprehensive survey of Hobart Town was carried out towards the end of an era of rapid population increase. The pattern of occupance and the characteristics of the buildings recorded by Sprent are examined after first tracing the physical growth of the town to the 1840s. The 1847 valuation of Hobart property is represented cartographically and related to physical and functional factors. Central area functions are analysed in detail and characteristics of commerce, manufacturing and port activity are presented. The persistence of Sprent's Hobart in the 1960s is shown by the assessment of townscape.

INTRODUCTION

There are several reasons why it might be maintained that Hobart's golden age was experienced in the last decade of the first half century of European settlement in Tasmania. Despite the cyclical depression of 1840-44 propounded by Hartwell (1954) the most fundamental uncertainties of earlier economic life had been significantly reduced by the 1840s through the development of local grain production and sheep rearing and by the establishment of various small but important manufactories. Frequent, and in part regular, shipping movements linked Hobart with ports both far and near. The town itself had attained a degree of functional differentiation and physical provision sufficient to draw comparison (as well as contrast) with older and larger centres. And in the context of colonial Australia Hobart enjoyed a relative importance which more than a hundred subsequent years have failed to recapture.

Hobart's relatively sedate progress is simply and fundamentally if not wholly explained by reference to hinterland relationships and geographical situation. What lesser features than the land beyond the Blue Mountains coupled with a continental gateway position, or the Mississippi lowlands combined with a mid-continental transport nodality can explain, in the broad, the respective growth of Sydney to a population of two million or of Chicago to seven million inhabitants in little more time than Hobart has taken to reach 120,000? This question is not, however, the chief concern of this paper, which is to portray the essential geographical character of Hobart Town toward the end of the colonial era. At the same time, the rather subdued rate of development of town and city in its second and third half centuries has left the present more clearly connected with the colonial past than would result from a history of more rapid change. Otherwise expressed, those readers who have some acquaintance with the subject of this paper should not find themselves on alien ground; rather it is hoped that they may be assisted to a new or better appreciation of their geographical environment.

PHYSICAL AND POPULATION GROWTH

Reference to Figure 1 shows the marked change in Hobart's population growth rate which occurred at about mid-century, when a period of almost complete stagnation began. Prior to that time the 'forties had seen a slowing of the processes, except Transportation, which had quintupled the population of the town in the space of 20 years: from 2700 in 1821 (Wentworth, 1824) to 14,602 at the Census of 1841. Even so, 21,467 inhabitants had accumulated in the Hobart Town Police District by the Census of 1847, at which time the whole of Van Diemen's Land counted 70,000 people.

It was not until the mid-thirties that the growth rates of the island and its capital began clearly to diverge. Settlement outside Hobart and Launceston was gaining momentum, and notably the coastlands west of the Tamar were on the threshold of development. By 1861 such potentials had become sufficiently realised to lift the island's population to within a few tens of 90,000, but Hobart lingered at 24,773. In the 1840s then, the town approached a population plateau, which can be viewed alternatively as a period of consolidation following several decades of continuous rapid increase, or as the end of an expansionist colonial era during which the town attained an importance in the Australian scene which the gold and golden fleece of the larger island to the north were soon to curb. In any event it was in 1841 that James Sprent began the survey of Hobart's streets and buildings that now forms an invaluable record of the physical structure of the colonial town.

Surveyor-General Sprent's meticulous plans were not the first to record the detailed lay-out of the Hobart settlement. The original camp between the rivulet and Sullivan Cove, with its handful of tents and huts, is recorded in Walker's collected papers (1950). Superimposed upon it is the street plan of 1811, laid down by Governor Macquarie, and comprising what have become the central urban blocks bounded by Harrington and Argyle, Davey and Liverpool Streets. There has in fact been no significant movement away from this initial focal area, although there have been changes of functional emphasis within it.

House Occupancy

By 1829 Hobart Town had acquired a population

of about 6000. Ross's Almanack of that year records 5700; Widowson writes of 6000-7000 people and about 1000 houses. A map of 1829* shows between 750 and 800 buildings in the more or less contiguously occupied area of the town, from which only Battery Point (then little built upon) and the more distant New Town settlement are excluded. This total is well supported by the 1831 record of 785 houses, enumerated by 22 streets and counting from as few as two in Antill to as many as 107 in Liverpool. If we exclude at least some tens of non-residential buildings from the 1829 total we are left with perhaps 700 houses.

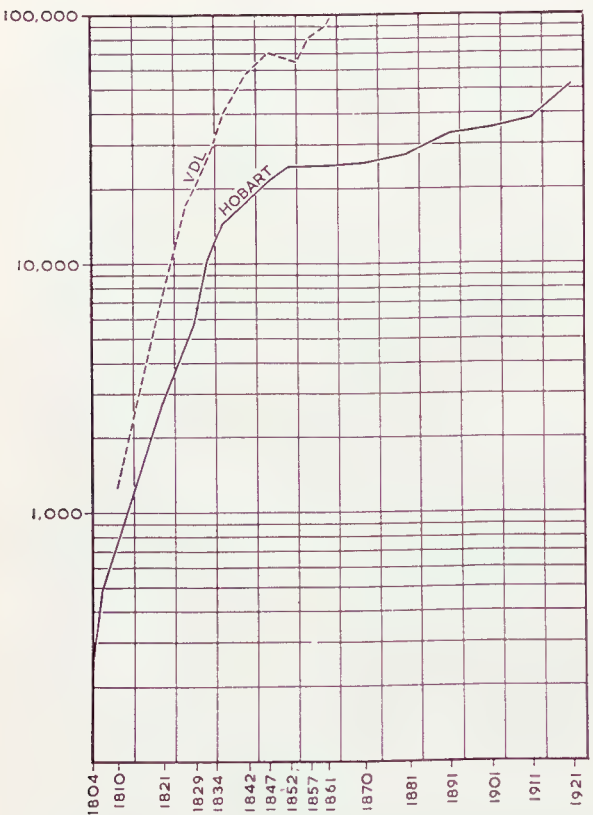

FIG. 1.—Early population growth of Hobart and Van Diemen's Land. Alternative interpretation of the figures available could produce a lower curve for Hobart between 1831 and 1852, but bearing a similar relationship to the growth rates before and after those dates. Source: Census Blue Books, almanacs, book references.

These had to accommodate 6000 people, less several hundred prisoners concentrated in the gaol and female house of correction, and a further concentration of soldiers in the barracks area. There may have been 5000 townspeople and assigned convicts in no more than 700 houses, which gives an approximate average rate of occupancy commensurate with nineteenth century family size. However, the sex ratio of the population was far from balanced—in 1831 there were 3102 free males to 2227 females—so we can infer a significant proportion of houses occupied by other than family groups. In fact the 1837 New Town Census can be used as a guide in this matter. A 13 per cent sample of the household returns shows a range of free occupants from 1 to 11, with a mean of 4.6, and of bonded people from 0 to 10, with a mean of 1.7; together, more than six people in an average household. According to visual and verbal records of the period many of the residences were cottages of small dimensions, so that four small rooms would represent fairly cosy living space for six people. On the other hand the more substantial "gentleman's residence" of two storeys could accommodate a much more numerous menage in comfort.

Building Materials

Figure 2 shows a distribution of buildings almost identical with that on the plan of 1829 mentioned above. It is therefore assumed to be of the same date, though the plan† on which it is based is undated. It provides a valuable period pattern of distribution of building materials, though the numbers of houses of particular fabric are recorded in early statistical returns. More than 40 per cent of the buildings, including nearly all the public buildings, were of brick or stone, indicating a fairly rapid incidence of these more permanent materials, since Prinsep (1833) reported that in 1819 the gaol-house was the only brick building, although freestone was coming into use. Durability of materials is usually associated with feelings of increasing stability in frontier settlements, and we can reasonably regard Hobart Town as normal in this respect. At the same time Macquarie's instruction (1814) after his 1811 visit that new buildings should be of stone or brick (and that buildings around the proposed George's Square—later to emerge as Franklin Square—should be of two storeys) may be regarded as reinforcing if not promoting an attitude of continuity and permanence.

The distribution of buildings in Figure 2 shows no significant areal differentiation of timber from brick and stone, outside the solid adminstration buildings and warehouses of the waterfront vicinity and the additional concentration of the barracks. It might be expected that a higher rate of brick construction in the years immediately preceding the survey would produce a rash of brick on the periphery, but as can be seen from the map sufficient vacant land remained at the centre for the process of infilling to be as active as that of peripheral extension, and so the pattern of materials at this time was haphazard.

Frankland's Plan

Another detailed plan of Hobart recording the physical advance of the town was the inset on

* Plan of Hobart 1829, *Intercolonial Exhibition of Industry Chart* 1866, Lands and Surveys Department, Hobart.

† Hobart No. 5, Lands and Surveys Department, Hobart.

FIG. 2.—Plan of Hobart Town *circa* 1829, showing distribution of main building materials.
Source: Hobart No. 5, Lands and Surveys Department, Hobart.

Frankland's 1839 map of Van Diemen's Land. Despite its small size (c. 9" x 8") and not very large scale (c. 1500 ft. to 1 inch) allotments and buildings are recorded. We can readily see the impact of a population increase from 6000 to about 14,000 in less than a decade, for the town blocks served by streets had doubled in area from about 500 to 1000 acres, mainly by the alienation of land on the northern and western boundaries of the area shown in Figure 2. However, this new town land was not uniformly occupied. In the south, buildings spread beyond Molle and Antill Streets to the town boundary at Elboden at comparable densities with the established adjacent blocks, while in the north between upper Murray Street (Veterans' Row) and Campbell the former general limit of Warwick was pushed forward to Burnett and the town boundary line of Arthur Street. But in the northwest the substantial area centred on Hill Street, though divided into allotments, had only

the lightest sprinkling of habitations. This was particularly true of the land rising sharply westward from Hill Street to Knocklofty Terrace, with the semi-circle of Crescent Fields (between Lansdowne Crescent and Hill Street) being quite untenanted. Battery Point now had the beginnings of non-military occupation, south of Hampden Road around Colville Street, though the southern slope of the hill down to the town boundary at Wellington (later Sandy Bay) Rivulet remained largely open country. The establishment long since of farms along the lower Derwent—Jeffreys (1820) reported that the Sandy Bay farms extended about five miles downstream, and Prinsep (1833) wrote that "the foot of Mt. Nelson is entirely laid out in gardens, fields, and little farmhouses, supplying Hobarton with plenty of fruit and vegetables"—meant that communication with this area was necessary, and that was achieved by way of Davey Street to the Barracks and then Byron Street to what is now Sandy Bay Road (Rowntree, 1959). Montpelier Retreat had not, by the time of Frankland's plan, extended continuously to the Wellington Rivulet to make an alternative connection with the southern outposts of settlement, but this deficiency had been remedied by the time James Sprent had conducted his survey.

SPRENT'S HOBART

James Sprent is probably best known for the skill with which he executed the first triangulation of Tasmania, since its accuracy has yet to be improved upon, but no less a contribution to posterity may be his building-by-building survey of Hobart, begun in February, 1841. The streets, allotments and buildings meticulously measured by Sprent are plotted on 74 sheets housed in the Lands and Surveys Department. Their individual accuracy (see Figure 3) need not be doubted, but combining the copied, re-drawn and reduced originals into the composite plan shown in Figure 4 provided very real technical problems. Sprent did not cover the area seaward of Macquarie Street between lower Murray Street and the outfall of the Hobart Rivulet. The shoreline and most of the buildings below the dotted line in the harbour environs of Figure 4 come from another plan* and slightly ante-date the earliest parts of Sprent's survey.

Pattern of the Built-up Area

The Hobart surveyed by Sprent was composed of more than 100 clearly bounded town blocks and a few irregular contiguous areas, the whole containing almost 2400 separate buildings. Their distribution (Figure 4) deserves some comment. Firstly, it is evident that 40 years after the foundation of the settlement the initial twin attractions of the harbour and the rivulet had not been superseded by other factors. The influence of geographical inertia would of course be strongly against any major shift in the centre of gravity unless serious disadvantages of the established area became apparent. Only one such disadvantage had been noted with any consistency by observers of the Hobart scene, and that concerned the rivulet itself. The low-lying area around its mouth was poorly drained, forming almost impassable swampy ground in winter (Widdowson, 1829). This was to be expected, since the Hobart Rivulet was joined by the lesser

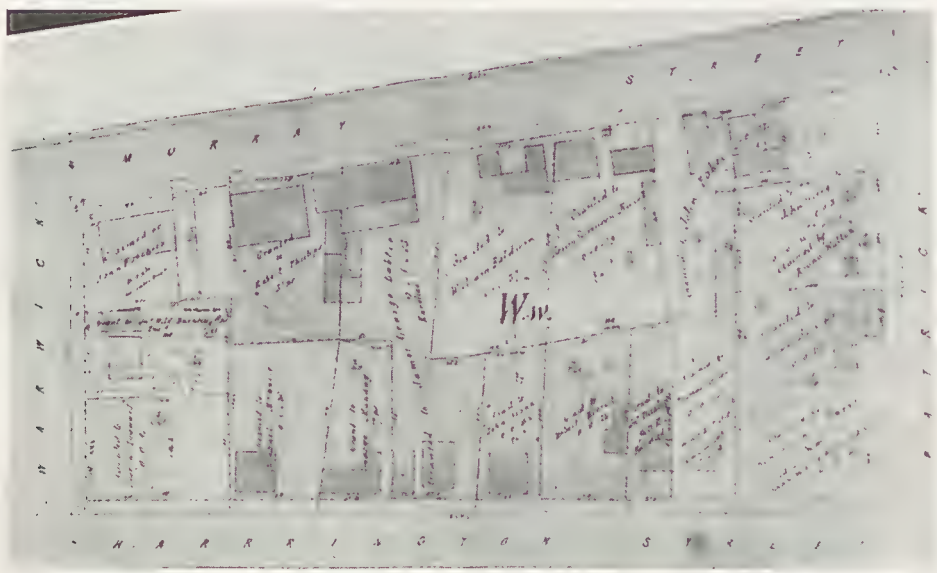

FIG. 3.—A section of Sprent's survey of Hobart. Reproduced by permission of the Surveyor-General.

* *Port of Hobart Town*, 12.11.1840, Hobart No. 19, Lands and Surveys Department, Hobart.

FIG. 4.—Hobart in the 1840s. Re-drawn and compiled from the survey by James Sprent.
Source: Sprent's survey plans and Hobart No. 19 (for area inside dashed line), Lands and Surveys Department, Hobart.

Domain (Park Street) Rivulet at the lowest point of Collins Street and then turned through more than a right angle to follow approximately the line of the Domain stream into the bay to the right of the Old Wharf (Hunter Street) causeway as in Figure 2. Clearly, the backing up of water at times of high flow was always a possibility at the confluence point, with the block between lower Collins and Macquarie Streets having the greatest potential for inundation. It is true that the course of the Hobart Rivulet has been increasingly restricted as commercial development has proceeded, but even so its capacity for flooding in its lowest reaches was convincingly demonstrated as late as April 1960, the area most affected being the same lower Collins Street vicinity, known as Wapping in earlier days. There is little doubt that the discharge problem in the 1820s was enhanced by the use of the rivulet as a receptacle for dead animals and refuse generally (Widowson, 1829; Breton, 1834), which pollution promoted the construction of an aqueduct to carry clean water to the barracks and some principal streets.

Figure 2 shows the considerable extent to which the inundable area had been built upon in 1829, and its comparison with Figure 4 reveals that a decade's reclamation had allowed the extension of Macquarie Street below the causeway and the formation of new land between it and Macquarie Point, together with some canalising and re-alignment of the lower rivulet.

By the time of Sprent's survey many of the town's inner blocks had been almost fully occupied, in the sense that most of their allotments carried buildings, but the density of buildings and the proportion of built-up land was notably highest in a few blocks between Murray and Argyle Streets. Elizabeth and Liverpool Streets clearly formed the main axes of building development. That they also fulfilled a leading functional role will be considered below. The commercial centre was partially separated from the waterfront by the Treasury buildings, Government House at the foot of Elizabeth Street, and the Commissariat Stores. However, it was not until the 1850s that the western shore of Sullivan Cove, shown in process of reclamation in Figure 4, became functional. In the 1840s the needs of shipping were served by Old Wharf, in which the original components of Hunter's Island and a tidally exposed spit were already barely recognizable; and by the more recently developed south (Battery Point) side known as New Wharf. Here the long established warehouses of Old Wharf were supplemented in the late 1830s by John Lee Archer's impressively designed Ordnance Stores near the battery from which the Point took its name; and at the foot of Kelly Street by the nucleus of stone warehouses which have made Salamanca Place an important piece of Australian architectural history.

At the corner of New Wharf and the western shore the fine new Custom House (also by Archer—see Smith, 1962), and the open market in front of it occupied previously swampy land built up during the construction of the wharf. Both of these were well placed to deal with the goods which were unloaded at their very doorstep.

Behind the row of warehouses the line of Kelly Street provided the main break in a substantially unoccupied area north of Hampden Road. Between the two the concept of Arthur's Circus is indicated by the subdivisional pattern, but building did not take place until about 1846, by which time Sprent was using his surveyor's chain elsewhere. Below (east of) the circus Secheron still occupied a position of splendid isolation, but subdivision was clearly about to change that. Further west, however, St. George's Church stood on the fringe of the southern slope of the ridge as yet wholly undeveloped (Plate VI).

Predictability of the Pattern

It is appropriate in examining Hobart's physical extent at or near the height of its colonial fortunes to ask whether the pattern of occupance had taken an expected or predictable form. Given the site selection of its founders, the answer is, in general, yes. Essentially settlement spread northwest along the depression between the two main areas of higher relief, the dolerite hill of the Queen's Domain and the sandstone and dolerite Knocklofty hill, while a southerly component followed the valley line of the Hobart Rivulet. The negative role of the Domain was not wholly physical since its reservation as Crown land undoubtedly prevented occupation by those who sought elevated sites, and were not inhibited by the equally steep and less proximate slopes of Knocklofty. Here the lightly dispersed houses had extended as far as the 400-foot contour above Lansdowne Crescent and to 330 feet on the ridge between Salvator Rosa's Glen and the Hobart Rivulet.

Other local eminences were well occupied: the Barracks looked across the town centre and the bay from 160 feet, almost from the first years of settlement, and from the early 1840s Trinity Church (replacing Old Trinity, or the Penitentiary Chapel) capped a hill of the same elevation which constituted the first real vantage point in a land surface which rose moderately to 100 feet half a mile from Sullivan Cove. The larger hill of Mount Nelson further down the Derwent estuary formed an excellent signal station site, but another century was to pass before it came into calculations for general residential occupation. Meantime its effect was to confine the Sandy Bay farms to the half mile-wide strip of land between the river and approximately the 300-foot contour.

In fact the limits of contiguous settlement in Hobart of the 1840s encompassed most of the low land having relatively unobstructed communication with the founding site. Thereafter the general extension of the urban area north and south along the river and to a lesser extent westward into the piedmont valleys of the Mt. Wellington massif began the attenuated plan of the present. The still compact settlement of Sprent's time was not without problems stemming from the basically hilly nature of the site as a whole and the adoption of a largely grid-pattern of streets. Some of the western streets ran steeply across rather than with the slope of the land, Molle Street, for instance, rising from less than 100 feet at the rivulet to almost 300 feet at Brisbane Street little more than 600 yards away—a gradient of one in nine. Stoney (1856) found it necessary to comment on the inconvenience attending the ascent of hills " so steep in some places as to cause great drawbacks to speedy

traffic—a matter of essential service in a trading town . . ."

It should be noted that street levels and gradients were not always quite the same as they are now; even a short history of settlement can provide buried evidence. Excavations for the revival of Cat and Fiddle Alley in 1960 revealed the lower rooms and barred windows of a stone building which had stood beside the early rivulet approximately 10 feet below the present surface of Murray Street between Collins and Liverpool. The gradient of Murray Street was therefore much steeper in that central valley zone, and the same is undoubtedly true of other cross streets before bridging operations raised the road levels. Dixon (1839) saw fit to comment on the consequences of such developments, as follows:—

> "Dwellings having been erected long before the streets were made, and the town being upon a very irregular surface, some of the buildings in consequence now occupy very awkward situations. On one side of a street, they are often elevated much above the level; while, on the other, they are sunk considerably beneath it."

Building Characteristics

We should not leave the physical aspects of Sprent's Hobart without some attention to its bricks and mortar. This synecdoche is not inappropriate, for by the census of 1841 over 71 per cent of the 2350 houses were of brick or stone compared with 40 per cent less than 20 years previous. The roofing materials were dominantly wooden shingles. Scott (1959) has examined the evolution of Hobart's building materials elsewhere, and attention is drawn to details (on page 160 of his paper) of the number and proportion of houses in brick and timber in each of the eight parishes of the built-up area in 1841. Although the red-orange "convict" brick undoubtedly outnumbered stone at all times, the extensive use of stone in the finer public buildings of the 1830s and 1840s is noteworthy.

The architectural qualities of a number of these have been discussed by others (Somerville, 1944; Sharland, 1957; Smith, 1962) but the family house deserves some comment here. The Misses Rowntree did much to arouse lay interest in our relict houses through writing and sketching their individual histories and architectural appeal. Compared with their labours of love any attempt to make collective generalisations may seem arid. However, it is possible to reduce the great variety of detail to a relatively few fundamentals of form and living space.

At the very simplest, the residents of Sprent's Hobart occupied two kinds of house: large and small. Examinations of Sprent's plans even at the scale of Figure 4, shows the relatively frequent occurrence of small buildings. The house depicted in Figure 5, until its demolition in 1966 for school extensions by the Education Department, was one of the smallest of Hobart's extant colonial cottages. It was certainly narrower than the typical Georgian cottage of one room and window on each side of the central doorway. Nevertheless, there were probably many more of its size, if not exactly its plan, than now remain. This cottage possessed no hall, and progress towards the rear was through successively narrower doorways, from 30 inches at the front to 27 inches between living and bedrooms and 20 inches at the kitchen. The first and middle rooms were of brick, but only the main room was under a pitched roof, allowing a horizontal lath and plaster ceiling 7′ 3″ above the floor. The timber kitchen under a skillion roof may have been an afterthought, but alternatively it may have served as a working base from which to construct the more substantial forward rooms, a procedure much more recently in vogue, after World War II. Curr (1824) referred to the practice of persons of small means building "a skilling or lean-to, which composes the rear of his future house, and as his means improve he erects a front". In the valuation lists of 1847 a few of these first-stage dwellings are recorded, so the practice enjoyed some continuity.

The ground plan of the house in Figure 5 measured about 28 feet by 12, whereas Macquarie's orders relating to the size of allotments (*Historical Records of Australia*, Series 3, Vol. 1, p. 512) envisaged houses of one-storey 36 by 14, and of two-storeys 40 x 16. While houses can be found that approximate these dimensions, frontages were usually shorter, even for rectangular houses; and many plans were square, thereby needing less allotment width and closely resembling the Sydney cottages of four rooms in a 30-foot square, plus detached kitchen at the rear, described by Boyd (1961).

Often the square plan Georgian house required a double-pitched roof, for until the ceiling joists were used to tie the feet of the rafters together the rafters rested on top of the walls and exerted an outward thrust upon them; the weight of the rafters and span of the roof had therefore to be limited, resulting for a single pitch in an essentially rectangular plan (Herman, 1954; Solomon, 1966). The house on the right in Plate I illustrates this limitation with its rectangular hipped roof followed by a long skillion, even though it is a large two-storey structure. The house on the left employs a steeper pitch to provide usable attic space, at the same time distributing the roof thrust evenly among the four walls (and probably providing structural support in the centre). In addition to the two main residential components of large (two-storey) and small (one-storey) buildings, a third distinctive element had been introduced by the 1840s: row houses. There is no obvious reason why this common form of construction should not have been introduced from England along with the Georgian style, except that in the early stages of settlement space was readily available and individuals preferred to use it for single detached houses. The higher density living of terrace housing implies economies of land and construction associated here with property investment and commercial rental developments rather than with any pressure on urban land resources. Mrs. Prinsep (1833), who noticed that there were houses of all shapes and sizes, also commented that "rows are even starting up here and there", but the present writer has not found any precise observations or statistics as to the total number of terraces. The attenuated plans of some of Sprent's buildings are suggestive of rows but not, in the absence of internal

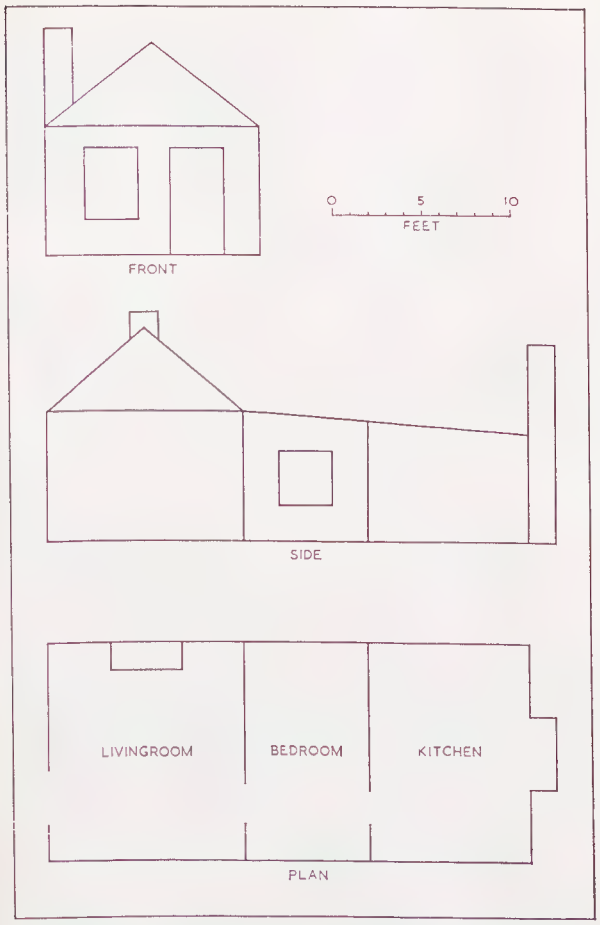

FIG. 5.—One of the smaller dwellings of colonial Hobart. Address, 283 Murray Street (formerly Veterans' Row). Demolished June, 1966. Source: Field survey.

subdivision and now of the buildings themselves, conclusive. However, a series of identical valuations coinciding with a "suspect" shape is considered sufficient supporting evidence, in a few cases actually confirmed by a designation such as Moodie's Row in the listings. On this basis upwards of a dozen rows of four or more units have been identified. One of a mere handful surviving is the subject of Plate II. Their original distribution was wide, but there was rather a concentration in the inner blocks north and east of Murray Street.

People per House

The number of residents per house was probably much the same in the 1840s as that estimated for the end of the 'twenties. The Census of 1841 showed 14,602 people. The maximum number of prisoners confined during the year ended September 1842 in the Hobart gaol, the male house of correction and the female house of correction, was 1,033 (but only 495 on September 30). Accommodation at the Barracks had spilled over into huts at the rear of the main building, with 344 officers and men in residence on September 30, 1842. We can therefore exclude about 1100 prisoners and soldiers from the population total, leaving 13,500 to be accommodated in the 2350 "houses" of the 1841 Census. These were almost certainly buildings of all kinds and the number of residences can be put in round figures (by comparison with the 1847 valuation evidence) at 2100. The average rate of occupancy comes again to between six and seven persons.

Observers' Impressions.

As a whole, the residences of Hobart were beginning to receive favourable reviews by the 1840s. In 1810 Lieut. Lord had been moved to comment that Hobart's houses were "indeed of the very lowest class of cottages" (though he found that the New Town settlers had "rendered their habitations comparatively comfortable—their white cottages in the midst of tolerable good gardens . . . .") and writing of 1820 Lloyd (1862) recalled that "the town then wore an exceedingly primitive appearance; there being in reality but fifteen or twenty buildings in it worthy the designation of dwelling-houses". A little later Mrs. Prinsep condescendingly observed that the chief part of the town was "judiciously hid in the valley behind" the principal buildings. However, Widowson (1829) thought that "the stranger will be gratified with the view of so many substantial houses, and well made M'Adamized streets," despite the small front gardens being poorly kept, and Breton (1834) found the houses improving though still inferior to Sydney's. Meredith (1852), who was a resident from 1840 to 1849, mentions the attraction of the gardens "before and between many houses" and by 1855 Mundy, though finding the wide streets "nearly as dusty, and the footpaths as ill paved as those of Sydney" considered that the trimness of the cottages surpassed Sydney's.

THE 1847 VALUATION OF HOBART PROPERTY.

Interesting as the observations of contemporary observers are, the light which they cast is not very specifically directed and we are fortunate in being able to turn to a source which can be used to amplify both these qualitative comments and the record of physical distribution provided by Sprent. This source is the Assessment List of 1847 which is the first comprehensive record of Hobart property values.*

The assessed annual value of each property is recorded, together with the rate payable by the occupier, the names of the occupier and the landlord, and the function of the property. These characteristics can be analysed without reference to area, but for the geographer the distributional aspects of such data are of fundamental interest. In this respect the first Assessment List is seriously deficient, for, while the properties are recorded by street, house numbers were not consistently or consecutively used and cross-street positions were not indicated. However, when plotted with constant reference to Sprent's plans the property values

* Assessment List, prepared by the Commissioners of the City of Hobart Town. *Hobart Town Gazette*, 32, 1601, 5 Jan. 1847, pp. 1-60.

could be accurately positioned within the town blocks. The area occupied by the valuated properties coincides almost completely with that of Sprent's survey, but there are wide variations in the degree of coincidence between owners' names and lot titles, depending, presumably, on the time-lag between the two assessments of each locality. It is clear that there was a considerable turn-over in property ownership within the space of the few years up to 1847; possibly reflecting the change from economic depression in the early 1840s to increasing prosperity in the latter years of the decade. There was also an increase in the number of buildings. Over 3300 property valuations appear in the 1847 list, of which 2458 were residential.

The assessed annual value of all the property in the urban area of 1847 was £101,000.* Of this total £5242 or 5.2 per cent was in the leading block bounded by Elizabeth, Murray, Liverpool and Collins Streets. The six leading blocks, numbered on Figure 6, formed a compact area between Argyle and Harrington, Collins and Bathurst Streets containing 22.6 per cent of the town's total valuation. The location of high-ranking blocks astride the rivulet was to be expected in the light of the building developments already discussed, but the position of the second and fourth blocks to the north of the first and third rather than south towards the water requires further explanation. Probably the higher ground on the north was favoured above that of the down side which was more susceptible to flood. Also, while access to the port was desirable, the western shore was under reclamation with Franklin Wharf not yet completed, and in any case direct access was barred by Government House and other public buildings. In fact by the middle of the twentieth century a southward shift in leading valuation totals towards the developed port had occurred. Meanwhile the second, fourth, fifth and sixth ranking blocks lay between the two nearest the original site and the bulk of the occupied areas to the north, west and south.

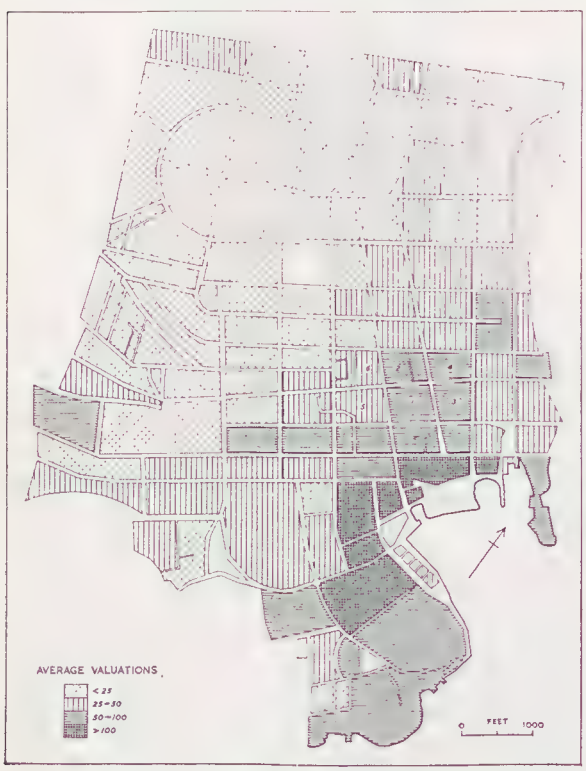

FIG. 6.—Property valuations 1847, by block averages, in £s. Inset numbers indicate blocks with highest total valuation of property. Source: Assessment List, *Hobart Town Gazette*, 5 January, 1847.

The main purpose of Figure 6 is to show the distribution of average property valuations by town block. The average of some thinly occupied blocks may have been less dependable guides to ultimate property conditions than those of more fully built-up inner areas; nevertheless, they reveal the situation as of 1847. A few blocks which lack any buildings in Figure 4 do have values in Figure 6, and vice versa, reflecting again differences in time of survey and of assessment in some areas.

It can be seen that the highest block average property valuations encircled the port. These were the only blocks in which the buildings received an assessment of more than £100, and they consisted largely of warehouses and public buildings, including Government House, the Custom House and the Treasury. Some of the more substantial of these occupied a lesser proportion of their block area than did central commercial and residential buildings, and their values averaged on a front-foot basis would be less dominant. However, the assessments relate to improved property consisting of land-and-building units, and the more highly improved properties may not unreasonably influence high average valuations. They are less likely to affect valuation totals unduly since their size tends to reduce the number of properties in the block.

The blocks in the second (£50-£100) category are for the most part adjacent to those in the highest category. They consist particularly of the central commercial area. From this hub they extend some distance southwest between Macquarie and Collins Streets, associated with good residential buildings rather than commercial properties. At the western end of Macquarie Street within the town lands one block owes its position as an outlier of relatively high value to its industrial character, for the area included two water mills and a brewery. On Battery Point, the largest extent of this valuation category outside the commercial centre stems from a leavening of shipyards and warehouses among the residential property, and across the bay warehouses and shops give the peninsula of Old Wharf similar valuation status. The two blocks divided by Kelly Street north of Hampden Road owe their differential rank (with averages of £102.6 and £51.7) to the greater representation of warehouses in the total property of the higher block.

If in fact we rank the 110 Hobart blocks containing assessed property in 1847 by quartiles, both these adjoining Battery Point areas are found in the fourth quartile, since the upper quartile value was only £47.1. By the same token, quartile rank-

* These are assessed rental values whose quantitative relationship to capital values is not known. Clearly, however, there must be a significant correlation between the capital worth of a building and its value for rental.

ing fails to differentiate as effectively among the higher value areas as the scatter-derived categories used in Figure 6, whereas an increase in the number of categories sufficient to bring out the higher value differentials produce too fragmentary an effect. Nevertheless the structural analysis of property distribution in Table 1 complements the visual pattern of Figure 6.

TABLE 1

Ranking of 1847 Property Valuations by Block Averages.

		Deciles	Value (£)
Number of blocks: 110		9th	75.60
Range of average values: £8.8 to £262.5		8th	52.35
		7th	39.50
		6th	32.45
		5th	28.35
		4th	21.65
Quartiles	Value (£)	3rd	19.35
Upper	47.10	2nd	16.25
Median	28.35	1st	13.60
Lower	17.60		

Source: Assessment List, *Hobart Town Gazette*, 32, 1601, 5 Jan. 1847.

The Pattern of Lower Values

The lower category town blocks of 1847 were dominantly residential, the sequence of houses broken sporadically by shops, hotels, schools, workshops and the like. This is more true of the sub-£25 average valuations than of the £25-£50 category, which involved areas of more diverse character. In the group of five blocks east of the business core, between Macquarie and Bathurst Streets, three had more than half their total valuations in residential property, but several other important functions were represented, including the hospital, the Theatre Royal, and a slaughter-house in Sackville Street. North of the highest block totals all but one of a group of nine blocks in the £25-£50 category had a frontage on Elizabeth Street, which continued its central commercial axis character. Commercial representation declined steadily northward though, and on the western side of Elizabeth Street the block averages fell from £44.5 between Bathurst and Melville to £26.5 between Brisbane and Patrick. On the east there was fluctuation rather than fall, with the six blocks between Bathurst and High (now Tasma) ranging between £35.9 and £29.6. In all of this zone the residential proportion of total valuation did not fall below 49 per cent for any block. On Trinity Hill the western slope leading to Elizabeth Street and with views of the mountain was clearly more desirable than the eastern side facing the Domain, since valuations were around £30 on the west and under £20 in the east.

Trinity Hill had a somewhat superior south-western counterpart in the vicinity of Fitzroy Place. On the ridge of land which continued eastward to the military barracks the Fitzroy-Davey Street Area contained Hobart's best concentration of residential property, with the possible exception of some valuable but more dispersed houses nearer the centre in and near Macquarie Street. The block bounded by Fitzroy, Davey, Molle and Antill averaged £48.2 per property, while the adjoining block with a frontage on Garden Crescent (Fitzroy Gardens) was lowest in the group west of the barracks with £35.3. In other words, the average values of this substantially residential area ranged around the upper quartile value of all Hobart's blocks of property at this time.

All 50 blocks in the lowest category of Figure 6 fall below the median value of £28.35. They were nearly all within the western half of the occupied area and comprised the bulk of it. There is no clear-cut grouping of values within this general distribution of the sub-£25 category, but it does appear that stage of development may have been more influential than other factors in providing such similarities and differences as occur between neighbouring blocks. This could operate through similarity of style and value in blocks developed at the same period, and through the fact that the few property units contributing to an average in areas just developing may not be typical of the more fully occupied block. This is instanced by the two blocks on either side of Warwick Street and bounded on the west by Hill Street. Their averages of £20.0 and £12.9, one well above and the other well below the lower quartile value, are notably discrepant. But on analysing the structure of the averages we find that the £20.0 derives from just one house, whereas the lower figure represents 36 residential and commercial properties. This is an extreme case, but it can be seen that in partly developed areas where improved values are modest the addition of a single high-value unit such as an hotel can raise the average significantly. It is also clear that site factors such as elevation were reflected in newly developing as well as more established areas; on the high side of Lansdowne Crescent above Poet's Road valuations exceeded £20 and on the urban periphery above Hamilton Street reached a surprisingly high £35. Below Lansdowne Crescent the handful of houses built between Sprent's survey and the 1847 assessment were only in the £12 and £15 range.

What relation the assessment of rental value for rating purposes (rates paid were 5 per cent of the assessment) bore the actual market rents has not been studied, but rents surely deserve consideration in social or economic histories of Hobart. In the present context of historical geography it will suffice to note that just as modern capital valuations for rating assessments tend to lie below market prices so do earlier valuations appear to fall short of rents demanded and paid for comparable dwelling space. Curr (1824) reported that cottages of 4-6 rooms commanded £60-£80 *per annum* and that two-storey houses of 8-10 rooms brought £120-£200. Widowson (1829) found house rents "very exorbitant": "a small cottage with only four rooms, and those of very contracted dimensions, and a kitchen at the back, will let for 60 to 80 pounds per annum" while "larger houses, adapted for stores, obtain from £200 to £300 per annum". These must surely have been extreme demands, even allowing for the influx of population, since by 1841 bricklayers', carpenters' and masons' wages were only seven to eight shillings per day (falling to a minimum of four shillings and eightpence by 1848) and it seems unlikely that these people could have afforded approximately half their earnings in rental of small cottages. Undoubtedly some of the artisans built and owned their dwellings

and others lived in the presumably cheaper-rent rows or terraces. But owners' and occupiers' names in the valuation records coincided insufficiently and row houses were too few to maintain that high rents would have been a charge only on the wealthy.

FUNCTION AND FUNCTIONAL AREAS.

The reader will be aware that the foregoing discussion of property valuations involved frequent reference to the functional character of those properties. Just as assumed function influences the price of land, so does actual function influence the nature and value of improvements to it—to the ultimate extent that churches were assumed to be valueless for the purposes of the 1847 assessment.

From the viewpoint of urban geography the functional structure of a town or city is the most vital of its facets to explore. Contemporarily this requires time and resources, but historically it also requires records of a kind which too often do not exist—at least in the distributional if not in the purely numerical sense. For Hobart for example, we have the statistical returns of the numbers of factories and hotels and occasional references to their location, size, or viability, but, from the functional designation of properties in the Assessment List, we can plot the precise location of nearly every functional unit. The resulting spatial relationships may be then analysed and the contribution of particular functions in particular areas assessed.

Inner Area Functions

It is not practicable here to reproduce the functional pattern of the whole of Sprent's Hobart, but Figure 7 illustrates the distribution of functions in 14 inner urban blocks, including the four blocks with highest property totals. The most noteworthy

FIG. 7.—Distribution of functional units in part of central Hobart in 1847.
Source: Assessment List, 1847.

feature is the concentration of functions along Elizabeth and to a lesser extent Liverpool Street. The great majority of these units consist of shop and residence, which was a combination found commonly throughout the commercial area. Its numbers are now much reduced in favour of offices, but two or three score after the style of Plate III may still be seen. Essentially the form was that of a two-storey house, with the living quarters above and the shop (with enlarged windows) at street level. A second feature to note is the prevalence of functional units, particularly houses, away from the street frontages in the interior block spaces. This is very true of the main block, where Cat and Fiddle Alley gave internal access and effectively extended the block frontages. Small unit size is a prerequisite for this kind of distribution, and as large functions such as department stores develop the interior units are forced out.

The share of major functions in the total property values of the blocks mapped in Figure 7 are given in Table 2, the blocks being numbered from top to bottom beginning on the left.

Commercial Characteristics

Perhaps the most striking feature of the inner area's functional structure revealed by Table 2 is the relatively small proportion of property value vested in commercial uses. Even the two most valuable blocks, 3 and 2 in the Table, have little more than 40 per cent of their assessed property in the shopping function, and only three of the 14 blocks have a greater proportion of total value in shops (and banks, where present) than in residences.

But this is to judge 1847 conditions by present standards, when shops may form upwards of 70 per cent of central area property. In the mid-nineteenth century retailing was by no means fully developed, and many richer households still traded directly with wholesalers or import agencies. Furthermore, competition for land was significantly less, functional selection was therefore slight, and as far as Hobart's functional structure was concerned, the whole process of urbanisation was in its infancy.

In fact the addition to the shopping sector of other commercial elements, notably hotels and warehouses, shows a substantially increased commercial component (column 4, Table 2) for some of the central blocks. The four most valuable (Blocks 3, 2, 7, 6) each contained more than 55 per cent of property value in commercial functions, and Blocks 4 and 11 below Collins Street even surpassed 60 per cent. The prevalence of warehouses and stores in Block 4 nearest the wharves is notable, even though the one warehouse in Block 9 represents a higher proportion of that area's property assets. In Blocks 13 and 14 nine hotels form the bulk of commercial values, far outstripping all other functions than the residential. This area behind Old Wharf was undoubtedly the sleazy end of town in colonial days although it was not alone in its substantial provision of public houses. Hobart's total of 152 in 1847 may even have surprised Lieut. Breton (1834) who found that our tally of 84 public houses gave us only one such establishment for every 78 free inhabitants, compared with Sydney's one for every 68. The small town block bounded by Harrington, Barrack, Liverpool and Goulburn Streets could claim, with eight inns, to be Hobart's leading alcohol dispensary, though in the centre of town Blocks 6 and 7 (Figure 7) provided 13 drinking places between them.

TABLE 2

Functional Proportions of Block Total Valuations.

Block	Total Valuation (£)	Shops & Banks (1)	Hotels (2)	Warehouses (3)	Total Commerce (4)	Residential (5)	Factories (6)	Offices (7)	Public Buildings (8)
1	2136	37.3	9.8	....	47.1	50.0	....	....	....
2	4497	41.6	12.7	....	55.7	42.6	0.8	....	0.9
3	5242	41.5	13.9	1.2	56.6	39.5	....	3.8	....
4	2720	29.1	12.1	19.9	61.1	28.9	....	1.5	8.6
5	1718	27.2	7.0	....	34.2	64.0	....	....	....
6	3285	31.0	24.4	1.5	55.4	43.2	....	....	....
7	3918	35.2	21.9	....	57.1	42.3	0.6	....	....
8	1662	33.9	....	....	33.9	46.6	....	8.7	10.8
9	678	7.4	....	22.1	29.5	60.2	....	....	10.3
10	1344	12.6	5.9	....	18.5	59.9	....	....	22.3
11	1379	41.0	21.8	....	62.8	31.0	6.2	....	....
12	585	....	....	....	....	100.0	....	....	....
13	1679	2.3	23.8	....	26.1	59.6	1.2	....	4.2
14	1290	13.4	31.2	....	44.5	44.3	11.2	....	....

Source: Assessment List, *op. cit.*

There is little doubt that some of the pubs, inns and taverns were primitive functional units, although only 39 of the 179 public houses licensed in Hobart Town on September 22, 1848 (*Statistics of VDL*, 1848) were recorded as being "of low character". The average valuation of the 1847 group was £83, compared with £97 for warehouses, £87 for factories and £30 for residences.

It might be thought from the proliferation of pubs that Sprent's Hobart was something of an affront to the travelled or sophisticated eye of the day. This may have been true of the settlement's first decade or two of existence, but as the mid-century approached the combination of solid Georgian buildings and increasing functional provision increased its standing as a place of some merit. Dixon (1839) allowed that despite the ubiquity of retail spirits stores—"stand at the corner of any street, and fifteen to twenty are in sight"—some of the shops were "showy and respectable, even tasteful and elegant; displaying an appearance equal to that of many in London". Sometime later Stoney (1856), while sanguine as to the town's prospects and lyrical of its surrounding natural beauty, found it deficient in order and cleanliness and was not as impressed by the public buildings as some previous observers who, for example, compared Macquarie Street favourably with its Sydney counterpart.

Manufacturing

It is fair to say that Hobart in the 1840s was regarded as an outpost of government, a convict repository and a trading town rather than a budding industrial centre. Nevertheless the 1841 Census* shows that while the town held 29 per cent of Van Diemen's Land population it possessed almost 38 per cent of those broadly defined as employed in manufacturing. Moreover the 1350 persons who provided this proportion were considerably more numerous than their co-workers in commerce (982) and agriculture (829). The Return of Manufactures† shows 22 industries and 86 enterprises in which Hobart's manufacturing workers could have been employed, to which the Arthur Street and Tolosa Street limestone quarries might be added. Even allowing for the inclusion in the manufacturing employment category of pursuits such as draper, tailor and tobacconist which we would now transfer to the commerce category, it seems unlikely that average employment per enterprise would have been 10 persons or more in the early 'forties in the light of labour shortage, scarcity of capital and the counter-attractions of primary production. In discussing these issues Hartwell (1954) concluded that manufacturing began to expand in VDL in the latter 'forties in response to growing community needs and the protection afforded local production by the enforced import reductions of the early part of the decade. He also asserted that "the owner-operator was the characteristic 'industrialist'" of the time, and in this he is supported by the record of few more than 30 mills, tanneries, workshops and the like in the Assessment List of 1847. Clearly some of the enterprises had the appearance of residences rather than industrial premises.

Even so, the Return of Manufactures reveals that Hobart Town had 17 mills in 1841 (VDL had 57), followed in descending order by 8 implement makers (23), 7 tanners (19), 6 breweries (21) and 6 cooperages. Probably the five ships and one steamer built by the town's shipyards were the only capital goods produced in 1841, and it seems the increased number and variety of manufactures by the end of the decade did not change the essentially consumer and maintenance orientation of manufacturing in either VDL or Hobart. In fact the manuscript Blue Book statistics itemise far fewer manufactories for Hobart in 1847 and 1848 than in 1841. These can only be regarded as incomplete since the island's manufacturing increased despite fluctuating fortunes, and basic producers in Hobart persisted. Thus the 17 mills and one sawmill of 1841 had become 19 flour mills (14 wind and water and 5 steam) and one sawmill in 1847. In that year the town also built 10 ships of from 17 to 418 tons, and in 1848 output increased to 18 ships totalling 1438 tons.

Compared with the somewhat introverted character of manufacturing trade was of course more outward-looking, though its conduct depended on internal as well as external factors. The most tangible of these as far as Hobart Town was concerned was the physical and functional development of the port.

Hobart's Port Function

Since the evolution of the Sullivan Cove area and the growth of the shipping for which it evolved have been examined in some detail elsewhere (Solomon, 1963), it is not proposed to repeat the analyses here. It is necessary, though, to stress the quite vital rôle which the port played in the morphology, activity and even mental concepts of the town. In this, Sprent's Hobart had no monoply, but it was a positive period.

Whatever else they criticised for its inadequacies Hobart's visitors and sometime residents waxed eloquent over the appearance and capacity of the port and harbour. From Collins' "most highly favourable" verdict on the settlement's situation in 1804, to Stoney's "commodious cranes and deep wharves afford every facility to lading and unlading merchandize" in 1856, the praise was consistent. As late as 1877 Sir Charles Du Cane told a British audience that "the special harbour of Hobart Town, I have been assured by naval officers, is without rival in the world for its combination of extent, safe anchorage, and accessibility in all weathers".

More specifically, despite problems of reduced capital inflow following the collapse of the late 'thirties boom, the foundations were laid in the 1840s for a port structure which was to last for a century. The southern shore of the Cove had been partly developed in the 1830s as New Wharf, and the clear task ahead was the development of the western shore, behind which lay the functional core of the town. Plans for reclamation and construction were produced as early as 1828, but not until 1839 did the work whose progress is illustrated in Figure 4 begin. One advantage of delay was that Governor Denison was enabled to take an interest in the project which resulted in the pro-

* Blue Book 1842, CSO 50 17, pp. 322-3. Accession 3334, State Archives.

† *op. cit.*, pp. 362 and 364.

TABLE 3
Hobart Shipping Arrivals 1837-1852.

Year	No. of ships	Tonnage recorded	Average tonnage per ship	Size Composition %				
				< 100 tons	100–199	200–499	500–999	1000–4999
1837	129	28,377	220	15	30	54	2	....
1838	186	43,882*	238	16	26	53	5	....
1839	207	45,764	221	30	18	49	3	....
1840	217	44,471	205	30	24	43	2	....
1841	271	53,745	198	30	30	36	4	....
1842	311	65,815	212	31	28	37	3	1
1843	151	32,371*	216	24	31	41	4	....
1844	232	47,513*	207	29	44	20	6	1
1845	263	49,228	188	36	34	24	5	0
1846	225	39,025	174	40	34	21	5	....
1847	367	59,612	163	44	32	21	3	0
1848	383	61,900	162	44	33	19	4	....
1849	398	65,941	166	41	35	19	5	....
1850	412	78,151	190	34	40	19	7	0
1851	486	87,563	181	24	51	21	4	....
1852	453	88,124	195	15	58	22	5	....

* Tonnage not recorded for two ships in 1838 and 1844 and for one in 1843.
Source: *Reports of Ships' Arrivals.* Accession 119, State Archives.

vision of Constitution Dock for the use of small craft. By 1850 the new western shoreline was established as Franklin Wharf but only a section just south of Fisherman's (now Victoria) Dock had been timber-decked. This was the base from which finger piers were soon to grow.

The island's imports and exports each dropped from more than £800,000 *per annum* for 1839 and 1840 to about half those figures by 1844. There followed a partial though not complete recovery in the later 1840s. Activity in the port of Hobart showed evidence of this recession, but its shipping decline was less sustained, and by the end of the decade completely erased.

Nevertheless it can be seen from the analysis of overseas and interstate shipping in Table 3 that the number of ships entering the port in 1842 was halved in 1843 and not equalled again until 1847. It took a further two years before the total tonnage of inwards shipping regained its 1842 level, and despite a general tendency to small fluctuation the average size of vessels clearly declined through the decade. The increased proportion of ships of less than 100 tons is noteworthy, implying a reduction in the overseas component which continued after the recovery in both numbers and total tonnages.

Coastal traffic between Hobart and Launceston increased steadily through the 1840s, perhaps as a complement to the mid-decade decline in external arrivals, which sometimes made coastal calls; more likely in response to growing population and production in the island. In fact the largest number of coastal movements in the period 1841-48 was 51 in 1843, the year in which "the depression reached its depth" (Hartwell, p. 226). However, compared with 28 inward and outward sailings in 1841 numbers were still high in 1846 (43) and 1847 (41), and tonnages grew from 2136 in 1841 to 3232 in 1843 and 5396 in 1847.

SPRENT'S HOBART IN THE 1960s

It was suggested in the introduction to this paper that Hobart's modest rate of growth as a capital city should assist the appreciation and understanding of its urban past. It is a truism that some things are more transient than others, and so the people of Sprent's Hobart are gone and their descendants are much more numerous than they; but some of the structures remain, a few of the plans are perpetuated, and our present is in no small measure shaped by the past. Part of Hobart's past has been geographically examined here, and an assessment of its physical link with the present will be the final purpose of this study.

But first, lest earlier comment and a popular awareness of its associations with history lead to a depreciated impression of Hobart's development, Figure 8 shows the progress and extent of the town's areal growth. The post-World War II expansion is notable, and despite the evolution of suburban nodes the pressures of functional development and change upon and within the colonial core are considerable. These are first observable in architectural modifications of the kind illustrated in Plate IV, and ultimately in the complete demolition of buildings whose size or plan no longer fit

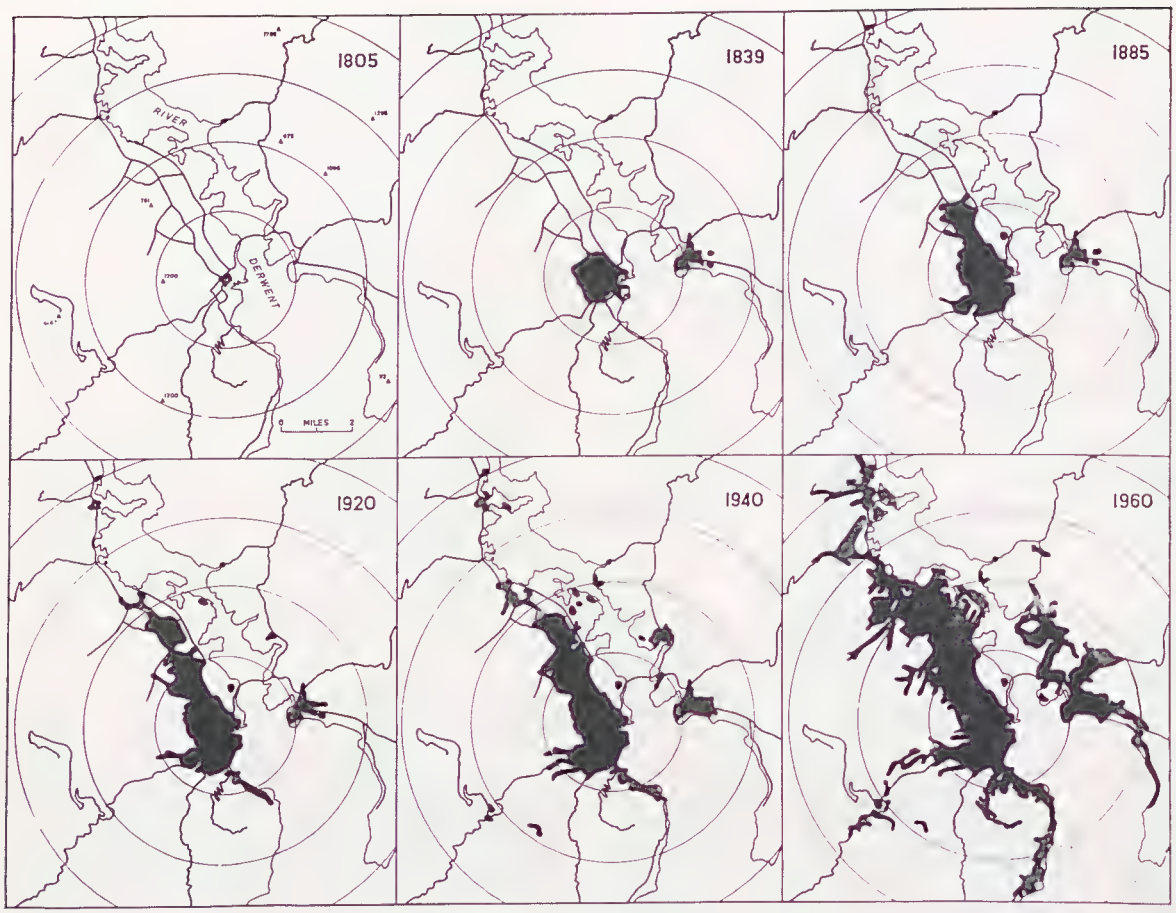

FIG. 8.—Expansion of Hobart's occupied area 1805-1960.
Source: Various plans.

their internal function or which stand in the path of changing land use and expanding services.

The simplest way to measure the extent of change (and perpetuation) is to survey the buildings of one period and seek them in another. Such an exercise is greatly supported by the existence of plans like Sprent's which can confirm assessments based on building styles and period characteristics. But merely to count a building present or absent is rather a crude measure of persistence, and takes no account of modifications to typical forms which singly and collectively influence their visual impact or townscape effect. Therefore the buildings in Figure 4 were assessed in the field and classified according to the degree of modification which each had sustained (Solomon, 1966). By applying a points scale with highest value for least change and lowest (score 0) for complete removal of the structure, block and area totals were found. Related to the maximum possible totals (of the original distribution) these provided a proportional measure of the preservation of Sprent's townscape in Hobart of 1962-63.

The degree of preservation by town block indicated in Figure 9 varied from 0 to 100 per cent. As the number of buildings per block varied considerably a high level of preservation in a particular block does not necessarily mean that the relict buildings concerned have a major share of the present townscape of the area. However, where a high percentage coincides with moderate density of occupation in Figure 4 it can be assumed that the buildings of Sprent's day are collectively important in the contemporary scene. Where the level of preservation is low the 1840s structures make little impact in the townscape of the 1960s. In a few areas, notably Battery Point, Georgian buildings erected after Sprent's survey add strength to the colonial element.

It was found by the method of assessment outlined that 24 per cent of the building fabric of Sprent's Hobart remained in 1962-63. The zone of greatest removal and replacement is shown in Figure 9 to be the commercial core or Central Business District, extending somewhat beyond the functional area represented in Figure 7. It is to

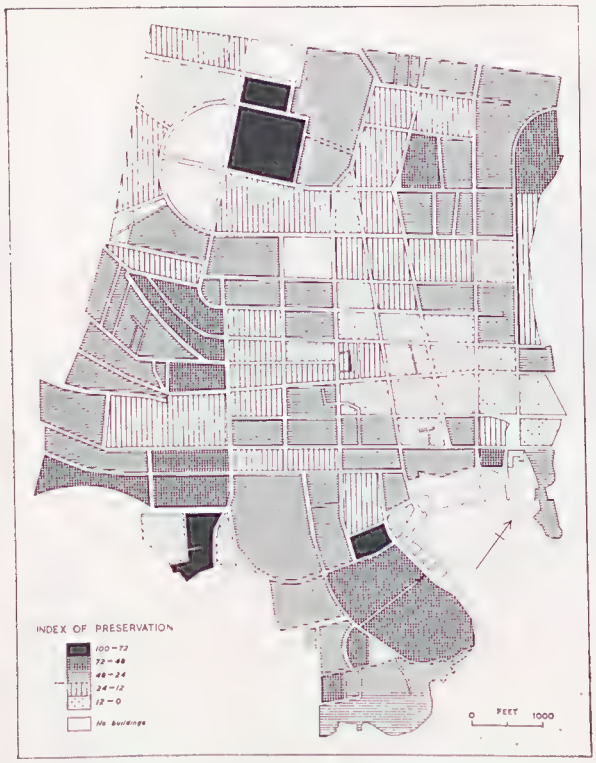

FIG. 9.—Preservation of Sprent's buildings in the townscape of the 1960s. The overall level is 24 per cent. Source: Field survey, 1962-63.

be expected that the maximum amount of change should take place here, particularly through the substitution of functions more appropriate to expensive central locations than some of the residences and warehouses of the 1840s. A low level of preservation extends along the northwesterly Elizabeth Street axis and similarly along the southwesterly Liverpool Street line until a pocket of high preservation is met beyond Molle Street. This area of West Hobart has counterparts in South Hobart and Battery Point, and with intervening blocks of moderate preservation they form an almost continuous band of notable historical persistence. Its substantially residential character is undoubtedly responsible for this, in contrast with the greater impact of change in North Hobart through commercial penetration.

In the short time since 1963 significant pieces of Sprent's Hobart have been removed, almost entirely as an accompaniment of functional change. In Burnett Street just east of Argyle Street one of the most concentrated pockets of colonial residences has been entirely obliterated to make way for increased traffic flow; in Davey Street another major concentration has been reduced by the demolition of the buildings in Plate I. With development in urban size and structure such change is inevitable, and townscape components as exemplified in Plates V and VI will disappear. But selective preservation of our developmental links should be made equally inevitable, acting from a basis of historical and geographical knowledge and understanding.

ACKNOWLEDGMENTS.

The author wishes to acknowledge the permission of the Surveyor-General to draw on plans in his keeping for the preparation of Figures 2, 3 and 4. The co-operation of the Chief Draughtsman, Mr. M. Phillips, in the use of these records is appreciated

Mr. P. Eldershaw, State Archivist, is warmly thanked for his ready advice and assistance with sources. This will not be the first paper which has barely done justice to the considerable source materials in his care.

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Plate I.—Two-storey houses of colonial origin. That on the left is typical of Hobart's larger Georgian buildings. The upper bay windows and second-storey skillion roof of that on the right are unusual. These houses were highly rated at £70 and £50 in the 1847 valuation. They were in Davey Street, near Antill Street, until replaced in 1965 by a service station.

Plate II.—Row houses in Davey Street. Few of these buildings remain in the 1960s. In 1847 four of the six units had a valuation of £14, the two in the middle with doors adjacent were rated (and presumably used) together at £28. A second row of six units then existed to the left of the present building.

Plate III.—Two-storey building in Liverpool Street representative of the shop and residence functional combination typical of the early commercial area. Residence above, shop with enlarged windows below.

Plate IV.—Modification to building fabric is shown in this enlargement of a residential doorway for industrial function. 4 Montpelier Retreat.

Plate V.—A distinctive section of Sprent's Hobart, removed in 1965: the Hobart Gaol in Campbell Street. In 1842 the maximum number of inmates at one time was 482.

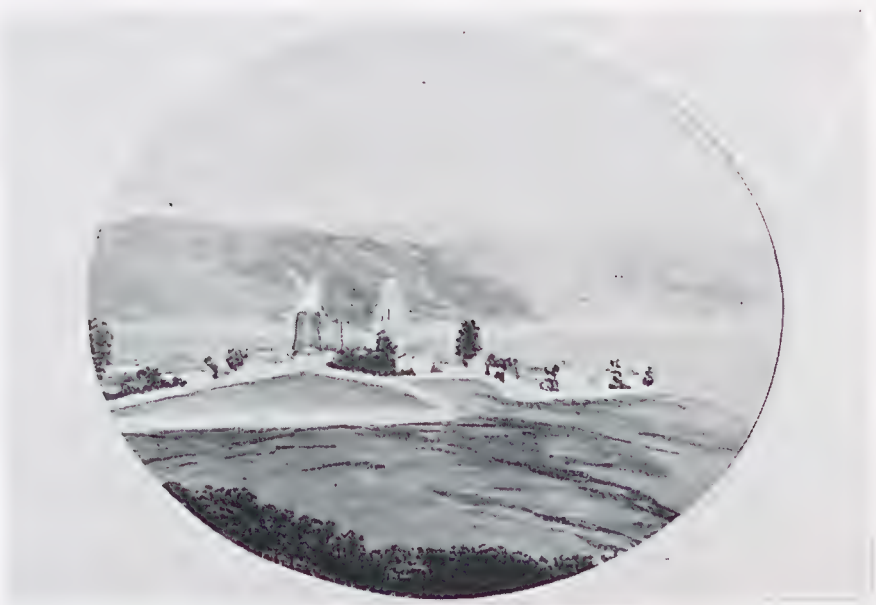

Plate VI.—A view of Battery Point from the west, *circa* 1845. The built-up area extended to the foreground (south of St. George's Terrace) soon after that time, and with the removal of the mill in 1885 St. George's Church alone dominated this townscape for 80 years. From a watercolour by Ellen Burgess, in the possession of Dr. C. Craig, Launceston.

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TERTIARY MOLLUSCAN TYPES FROM TABLE CAPE IN THE TASMANIAN MUSEUM, HOBART

By

N. H. Ludbrook*

ABSTRACT

Figures and synonymies are given of the fifty-one primary types of Mollusca described from the Tertiary beds of the Table Cape Group which remain in the Tasmanian Museum.

INTRODUCTION

During a visit to Hobart in August, 1965, for the meeting of the Australian and New Zealand Association for the Advancement of Science, the writer was kindly given permission by the Director of the Tasmanian Museum to examine and photograph the Table Cape fossil molluscs described by Tenison Woods in 1876 and 1877. These, together with some described by Johnston between 1877 and 1888 and by May in 1919 and 1921, form an important collection of primary types, most of which have been figured by drawings only, but some have remained unfigured. Eleven of the species were not listed by Crespin (1964).

Although the collection represents only a small percentage of the material described by Tenison Woods and Johnston, it appears to be all that remains in Hobart.

With the exception of ten small species figured on Plate 2, the photographs illustrating this paper were taken with a Zeiss Contaflex IV 35 mm camera, the light source being two Leitz MONLA microscope lamps. Mr. M. R. Banks kindly made arrangements for the small specimens to be photographed in the Geology Department of the University of Tasmania. Unless otherwise stated, all specimens are reproduced at natural size. Some of the types could not be well oriented because they are glued to cardboard mounts.

STRATIGRAPHIC SETTING

The Table Cape Mollusca were collected from the two formations comprising the Table Cape Group (Banks, 1962). The lower, the Freestone Cove Sandstone, is the "Crassatella Bed" of Johnston (1877, p. 84) and the upper, the Fossil Bluff Sandstone, is Johnston's "Turritella Group" (1. c. p. 82). The richest molluscan fauna is in the Freestone Cove Sandstone.

The Table Cape Group has usually been assigned to the Janjukian Stage in the broad sense of Singleton 1941, that is, representing the interval of time required for the deposition of the two formations described by Raggatt and Crespin (1955) as the Jan Juc and the Puebla Formations. The molluscan fauna of the "Crassatella Bed" was by Pritchard (1896, p. 77) regarded as the "direct equivalent of the so-called middle beds of the Spring Creek section in Victoria", i.e. with part of the Puebla Formation and of early Longfordian and not Janjukian age. Although the microfaunas from the Freestone Cove and Fossil Bluff Sandstone have not been studied, they appear to be of Longfordian age, equivalent to Carter's (1959) faunal unit 6. This represents the highest occurrence of *Sherbornina atkinsoni* which in the Freestone Cove Sandstone is associated with benthonic foraminifera of Miocene aspect not known in South Australia or Gippsland (Carter, 1964) to occur below the Longfordian.

The planktonic foraminifera are consistent with those of Unit 6. As there appears to be fairly general acceptance of a Miocene age for sediments containing Unit 6, the Table Cape Group is of Lower Miocene rather than Upper Oligocene age.

TYPES OF THE TABLE CAPE MOLLUSCA

The Table Cape types are listed below under their registered numbers and original names. A brief synonymy is then given under the name (in bold type) which should now be used for the species so far as could be determined from the relatively brief examination. All types are holotypes unless otherwise stated.

Leda crebrecostata Tenison Woods Z178, pl. 2, fig. 40.

Nuculana (Scaeoleda) crebrecostata (Tenison Woods)

1877. *Leda crebrecostata* Tenison Woods, p. 112.

1886. *Leda crebrecostata;* Tate, p. 133, pl. V, figs. 5a-b.

1955. *Nuculana (Scaeoleda) crebrecostata;* Ludbrook, p. 20, pl. 1, fig. 6.

Nuculana rhomboidea May Z182, pl. 2, fig. 41.

Ledella rhomboidea May

1921. *Nuculana rhomboidea* May, p. 12, pl. 4, fig. 9.

Cucullaea cainozoica Tenison Woods Z204, pl. 1, figs. 7-12.

Glycymeris (Glycymeris) cainozoica (Tenison Woods)

1877. *Cucullaea cainozoica* Tenison Woods, p. 111.

1886. *Pectunculus cainozoicus;* Tate, p. 136, pl. X, figs. 8a, 8b.

1888. *Pectunculus cainozoicus;* Johnston, pl. XXXI, figs. 13, 13a.

* Geological Survey of South Australia; published with the permission of the Director of Mines.

1925. *Glycymeris cainozoica*; Chapman and Singleton, p. 20, pl. I, figs. 1a, 1b, 2a, 3, 4; pl. IV, figs. 1, 2, 3.

1965. *Glycymeris* (*Glycymeris*) *cainozoica;* Ludbrook, p. 87, pl. 1, figs. 28-34.

The holotype designated by Chapman and Singleton is that figured on pl. 1, figs. 11, 12; the complete specimen of two valves, figs. 7-10, is the paratype.

Crassatella oblonga Tenison Woods Z174, pl. 1, figs. 1, 3.

Eucrassatella oblonga (Tenison Woods)

1876. *Crassatella oblonga* Tenison Woods, fig. XI, p. 25.

1876. *Crassatella aphrodina* Tenison Woods, fig. XII, p. 24.

1888. *Crassatella oblonga*; Johnston, pl. XXIX, figs. 1, 1a.

1888. *Crassatella aphrodina;* Johnston, pl. XXIX, fig. 2.

1896. *Crassatella oblonga;* Pritchard, p. 131.

1896. *Crassatella aphrodina*; Pritchard, p. 131.

1965. *Eucrassatella oblonga*; Darragh, p. 99, pl. 12, figs. 4, 9, 10.

Crassatella aphrodina Tenison Woods Z199, pl. 1, figs. 4, 5.

Eucrassatella oblonga (Tenison Woods)

Darragh (p. 101), in supporting the synonymy of *Crassatella aphrodina* with *Crassatella oblonga*, recommends retention of the more familiar name *oblonga* although *aphrodina* has page priority. This would disregard the International Rules of Zoological Nomenclature. However, if one accepts that the figures of *oblonga* and *aphrodina* follow page 12, and precede the description, then *oblonga* has priority.

Cardita gracilicostata Tenison Woods Z177, pl. 2, figs. 46, 47.

Glans gracilicostata (Tenison Woods)

1877. *Cardita gracilicostata* Tenison Woods, p. 112.

1886. *Cardita gracilicostata;* Tate, p. 152, pl. II, figs. 6, 8.

1927. *Venericardia gracilicostata;* Chapman and Singleton, p. 118, pl. 11, figs. 20, 21.

Chama lamellifera Tenison Woods Z193, pl. 1, fig. 2.

Chama lamellifera Tenison Woods

1877. *Chama lamellifera* Tenison Woods, p. 114.

1887. *Chama lamellifera*; Tate, p. 149, pl. XIV, figs. 5a, 5b.

Solecurtus legrandi Tenison Woods Z176, pl. 2, fig. 45.

Solecurtus legrandi Tenison Woods

1876. *Solecurtus legrandi* Tenison Woods, fig. XIV, p. 25.

1887. *Solecurtus legrandi*; Tate, p. 181, pl. XVII, fig. 15.

1888. *Solecurtus legrandi;* Johnston, pl. XXXII, fig. 18.

Lyonsia agnewi Tenison Woods Z190, pl. 1, fig. 6.

Panopea agnewi (Tenison Woods)

1876. *Lyonsia agnewi* Tenison Woods, fig. XIII, p. 25.

1887. *Panopaea agnewi*; Tate, p. 179.

1888. *Panopaea agnewi*; Johnston, pl. XXIX, fig. 3.

Thalotia alternata Tenison Woods Z168, pl. 2, figs. 19, 20.

Thalotia alternata Tenison Woods

1877. *Thalotia alternata* Tenison Woods, p. 97.

Gibbula aequisulcata Tenison Woods Z175, pl. 2, fig. 25.

Gibbula (Notogibbula) aequisulcata Tenison Woods

1877. *Gibbula aequisulcata* Tenison Woods, p. 98.

1919. *Gibbula aequisulcata*; May, p. 70, pl. VIII, fig. 3.

Gibbula crassigranosa Tenison Woods B59, pl. 2, fig. 18.

Gibbula (?) crassigranosa Tenison Woods

1877. *Gibbula crassigranosa* Tenison Woods, p. 98.

1919. *Gibbula crassigranosa;* May, p. 70, pl. VIII, fig. 4.

The generic location of this species is uncertain.

Solarium (*Torinia*) *gibbuloides* Tenison Woods unnumbered, pl. 2, fig. 17.

Antisolarium gibbuloides (Tenison Woods)

1877. *Solarium* (*Torinia*) *gibbuloides* Tenison Woods, p. 97.

1896. *Delphinula gibbuloides*; Pritchard, p. 122.

1919. *Solarium* (*Torinia*) *gibbuloides*; May, p. 70, pl. VIII, fig. 5.

Astralium (*Calcar*) *ornatissimum* Tenison Woods Z194, pl. 2, fig. 16.

Astralium (Bellastraea) ornatissimum Tenison Woods

1877. *Astralium* (*Calcar*) *ornatissimum* Tenison Woods, p. 96.

Imperator hudsonianum Johnston Z167, pl. 2, figs. 7, 8.

Astralium hudsonianum (Johnston)

1888. *Imperator hudsonianum* Johnston, pl. XXIX, figs. 12, 12a.

1896. *Astralium* (*Imperator*) *johnstoni* Pritchard, p. 116.

Turbo etheridgei Tenison Woods Z202, pl. 2, fig. 15.

Turbo (Euninella) tenisoni Finlay

1877. *Turbo etheridgei* Tenison Woods, p. 98 (*non* Lycett, 1857).

1927. *Turbo tenisoni* Finlay, p. 493 (nom. nov.).

Rissoina johnstoni Tenison Woods Z180, pl. 2, fig. 32.

Rissoina johnstoni Tenison Woods

1877. *Rissoina johnstoni* Tenison Woods, p. 101.

The generic placing of this species is doubtful until it can be more closely examined.

Haurakia crassicosta May Z158, pl. 2, fig. 27.

Haurakia crassicosta May

1921. *Haurakia crassicosta* May, p. 11, pl. IV, fig. 6.

Potamides semicostatum Tate B83, pl. 4, fig. 15.

Thericium (Chavanicerithium) pritchardi (Harris)

1885. *Potamides semicostatum* Tate, p. 226. (*non* Deshayes)

1897. *Cerithium pritchardi* Harris, p. 225, pl. VII, fig. 3 (nom. nov.)

1957. *Thericium (Chavanicerithium) pritchardi*; Ludbrook, p. 30.

Crepidula hainsworthii Johnston Z165, pl. 2, figs. 35, 36, 37.

Crepidula (Zeacrypta) hainsworthi Johnston

1885. *Crepidula hainsworthii* Johnston, p. 233, pl.

1888. *Crepidula hainsworthii* Johnston, pl. XXXII, figs. 13, 13a, 13b.

1893. *Crepidula hainsworthi*; Tate, p. 330.

1957. *Crepidula (Zeacrypta) hainsworthi*; Ludbrook, p. 53, pl. 4, figs. 13, 14.

Crepidula umbilicata Johnston Z170, pl. 2, figs. 38, 39.

Calyptropsis umbilicata (Johnston)

1885. *Crepidula umbilicata* Johnston, p. 323, pl.

1888. *Crepidula umbilicata* Johnston, XXXII, figs. 10, 10a.

1893. *Calyptropsis umbilicata*; Tate, p. 333.

Triton minimum Tenison Woods Z189, pl. 2, fig. 26.

Charonia (Austrosassia) tortirostris (Tate)

1877. *Triton minimum* Tenison Woods, p. 107 (*non* Hutton).

1888. *Triton tortirostris* Tate, p. 124, pl. V, fig. 7.

1903. *Tritonium (Sassia) tortirostris*; Cossmann, p. 95.

1931. *Austrosassia tortirostris*; Finlay, p. 10.

Triton abbotti Tenison Woods Z188, pl. 2, figs. 1, 2.

Charonia (Austrosassia) abbotti (Tenison Woods)

1876. *Triton abbotti* Tenison Woods, fig. VIII, p. 24.

1888. *Triton abbotti*; Johnston, pl. XXIX, fig. 13; pl. I, fig. 8.

1888. *Triton abbotti*; Tate, p. 117.

1903. *Tritonium (Austrotriton) abbotti*; Cossmann, p. 99.

1931. *Austrosassia abbotti*; Finlay, p. 9.

Cassis sufflatus Tenison Woods Z201, pl. 2, figs. 9, 10.

Semicassis (Antephalium) sufflata (Tenison Woods)

1877. *Cassis sufflatus* Tenison Woods, p. 93.

1889. *Semicassis sufflata;* Tate, p. 165.

1896. *Semicassis sufflata;* Pritchard, p. 106.

Natica vixumbilicata Tenison Woods Z179, pl. 2, figs. 11, 12.

Polinices (Conuber) vixumbilicata (Tenison Woods)

1877. *Natica vixumbilicata* Tenison Woods, p. 111.

1893. *Natica vixumbilicata*; Tate, p. 320, pl. X, fig. 9.

Two specimens bear the number Z179, the smaller of which has the dimensions cited in the original description. This is here designated lectotype and figured (pl. 2, figs. 11, 12).

Natica polita Tenison Woods Z206, pl. 2, figs. 5, 6.

Friginatica polita (Tenison Woods)

1876. *Natica polita* Tenison Woods, fig. IV, p. 23.

1893. *Natica polita;* Tate, p. 325.

Natica wintlei Tenison Woods Z197, pl. 2, figs. 13, 14.

Friginatica wintlei (Tenison Woods)

1876. *Natica wintlei* Tenison Woods, fig. III, p. 23.

1888. *Natica wintlei*; Johnston, pl. XXIX, fig. 10.

1893. *Natica wintlei;* Tate, p. 322.

Voluta pellita Johnston Z156, pl. 4, figs. 9, 10.

Ericusa (Mesericusa) pellita (Johnston)

1880. *Voluta pellita* Johnston, p. 36.

1888. *Voluta pellita* Johnston, pl. XXX, fig. 2.

1896. *Voluta pellita;* Pritchard, p. 97.

1949. *Ericusa pellita*; Cotton, p. 186.

Voluta lirata Johnston Z185, pl. 3, figs. 5, 7.

Notopeplum saginatum Finlay

1880. *Voluta lirata* Johnston, p. 37 (*non* Brocchi, *nec* Sowerby).

1927. *Notopeplum lirata*; Finlay, p. 514.

1930. *Notopeplum saginatum* Finlay, p. 45 (*non Voluta lirata* Tate, 1889, p. 130, pl. II, fig. 4) (*non Voluta (Aulica) lirata* Harris, 1897, p. 103, pl. IV, fig. 12).

1949. *Notopeplum saginatum*; Cotton, p. 191.

1949. *Nannamoria lirata*; Cotton, p. 192.

Voluta mortoni Tate Z208, pl. 3, figs. 6, 8.

Pterospira mortoni (Tate)

1889. *Voluta mortoni* Tate, p. 124, pl. IX, fig. 1.

1897. *Voluta (Pterospira) mortoni*; Harris, p. 100.

1949. *Pterospira mortoni*; Cotton, p. 187, pl. XV, fig.

Voluta stephensi Johnston Z183, pl. 3, figs. 3, 4.

Alcithoe (Cottonia) stephensi (Johnston)

1880. *Voluta stephensi* Johnston, p. 35.

1888. *Voluta stephensi* Johnston, pl. XXX, fig. 1.

1889. *Voluta stephensi*; Tate, p. 122.
1896. *Voluta stephensi;* Pritchard, p. 94.

Voluta tateana Johnston Z187, pl. 4, figs. 1, 2.
Notovoluta tateana (Johnston)
1880. *Voluta tateana* Johnston, p. 37.
1888. *Voluta tateana* Johnston, pl. XXX, figs. 3, 3a.
1889. *Voluta tateana*; Tate, p. 132, pl. II, fig. 5.
1949. *Notovoluta tateana*; Cotton, p. 194, pl. XIV, fig.

Voluta stolida Johnston Z186, pl. 3, figs. 9, 10.
Paramoria stolida (Johnston)
1880. *Voluta stolida* Johnston, p. 36.
1888. *Voluta stolida* Johnston, pl. XXX, figs. 4, 4a.
1896. *Voluta stolida* var. *stolida*; Pritchard, p. 94.
1949. *Cymbiola stolida*; Cotton, p. 189.

Voluta weldii Tenison Woods Z191, pl. 3, figs. 1, 2.
Paramoria weldi (Tenison Woods)
1876. *Voluta weldii* Tenison Woods, fig. II, p. 24.
1888. *Voluta weldii*; Johnston, pl. XXX, fig. 6b (not figs. 6, 6a, 7).
1889. *Voluta weldii*; Tate, p. 134.
1896. *Voluta weldii*; Pritchard, p. 93.
1897. *Voluta (Aulica) weldi*; Harris, p. 102.
1949. *Cymbiola weldii*; Cotton, p. 189.

Marginella atkinsoni May Z159, pl. 2, fig. 30.
Marginella (Eratoidea) atkinsoni May
1921. *Marginella atkinsoni* May, p. 9, pl. 4, fig. 1.
1949. *Marginella atkinsoni* Cotton, p. 217, pl. XVII, fig.

Marginella corpulenta May Z160, pl. 2, fig. 28.
Marginella (Eratoidea) corpulenta May
1921. *Marginella corpulenta* May, p. 9, pl. IV, fig. 2.
1949. *Marginella corpulenta*; Cotton, p. 217, pl. XVII, fig.
The holotype has been broken.

Marginella subquinquidens May Z161, pl. 2, fig. 29.
Marginella (Eratoidea) subquinquidens May
1921. *Marginella subquinquidens* May, p. 10, pl. IV, fig. 3.
1949. *Marginella subquinquidens*; Cotton, p. 218, pl. XVII, fig.

Marginella altispira May Z162, pl. 2, fig. 31.
Marginella (Dentimargo) altispira May
1921. *Marginella altispira* May, p. 10, pl. IV, fig. 5.
1949. *Marginella altispira*; Cotton, p. 219, pl. XVII, fig.

Fusus johnstoni Tenison Woods Z173, pl. 4, figs. 5, 6.
Latirus (Brocchitas) johnstoni (Tenison Woods)
1877. *Fusus johnstoni* Tenison Woods, p. 94.
1888. *Fusus johnstoni*; Johnston, pl. XXIX, fig. 9.
1888. *Fusus johnstoni*; Tate, p. 136, pl. XII, figs. 4a, 4b.

Fusus transenna Tenison Woods Z172, pl. 2, figs. 33, 34.
Fusinus (Microcolus) transenna (Tenison Woods)
1877. *Fusus transenna* Tenison Woods, p. 94.
1888. *Peristernia transenna*; Tate, p. 157, pl. XI, fig. 10.

Cominella lyraecostata Tenison Woods Z203, pl. 2, figs. 23, 24.
Phos lyraccostatus (Tenison Woods)
1877. *Cominella lyraecostata* Tenison Woods, p. 108.
1888. *Phos liraecostatus*; Tate, p. 167, pl. XI, fig. 12.

Cominella cancellata Tenison Woods Z192, pl. 2, figs. 21, 22.
Belophos woodsi (Tate)
1877. *Cominella cancellata* Tenison Woods, p. 107.
1888. *Bela woodsii* Tate, p. 147, 173, pl. IV, fig. 3.
1901. *Belophos woodsi*; Cossman, p. 163.
1944. *Belophos woodsi*; Powell, p. 25.
The writer has not so far confirmed the homonymy of *C. cancellata*.

Typhis McCoyi Tenison Woods Z196, pl. 2, figs. 3, 4.
Typhis (Typhina) maccoyi Tenison Woods
1876. *Typhis McCoyi* Tenison Woods, fig. V, p. 22.
1888. *Typhis McCoyi*; Johnston, pl. XXIX, fig. 11.
1888. *Typhis McCoyii*; Tate, p. 91.
1903. *Typhis (Typhina) M'Coyi*; Cossmann, p. 58, pl. II, fig. 16.
1961. *Typhis (Typhis) maccoyi*; Vella, p. 383, pl. 47, fig. 25, text fig. 4 (10).
1964. *Typhis (Typhina) maccoyi;* Keen and Campbell, p. 48, pl. 8, fig. 8.

Terebra simplex Tenison Woods B48, pl. 4, fig. 16.
Hastula (Nototerebra) tenisoni (Finlay)
1876. *Terebra simplex* Tenison Woods, fig. I, p. 21 (*non* Conrad, *nec* Carpenter).
1889. *Terebra simplex*; Tate, p. 162.
1927. *Terebra tenisoni* Finlay, p. 520 (*nom. nov.*)
1958. *Hastula (Nototerebra) tenisoni*; Ludbrook, p. 100, pl. 6, fig. 9.

Terebra additoides Tenison Woods, Z200, pl. 2, fig. 44.
Strioterebra (Pervicacia) additoides (Tenison Woods)
1877. *Terebra additoides* Tenison Woods, p. 95.
1889. *Terebra additoides*; Tate, p. 163.

Turris conspicua May Z157, pl. 4, figs. 13, 14.
Zemacies conspicua (May)
1921. *Turris conspicua* May, p. 11, pl. IV, fig. 7.

Pleurotoma paracantha Tenison Woods Z205, pl. 4, figs. 3, 4.
Optoturris paracantha (Tenison Woods)
1877. *Pleurotoma paracantha* Tenison Woods, p. 105.
1898. *Bathytoma paracantha*; Tate, p. 398.
1944. *Optoturris paracanthus*; Powell, p. 12.
1964. *Optoturris paracantha*; Powell, p. 296.

Turris altispira May B772, pl. 4, figs. 7, 8.

Apiotoma altispira (May)

1921. *Turris altispira* May, p. 12, pl. IV, fig. 5.

Daphnella gracillima Tenison Woods Z207, pl. 4, figs. 11, 12.

Teleochilus gracillimus (Tenison Woods)

1877. *Daphnella gracillima* Tenison Woods, p. 106.

1944. *Teleochilus gracillimus*; Powell, p. 64.

Turbonilla liraecostata Tenison Woods Z210, pl. 2, fig. 42.

Turbonilla (Chemnitzia) liraecostata Tenison Woods

1877. *Turbonilla liraecostata* Tenison Woods, p. 101.

Actaeon scrobiculatus Tenison Woods Z211, pl. 2, fig. 43.

Acteon scrobiculatus Tenison Woods

1877. *Actaeon scrobiculatus* Tenison Woods, p. 102.

1897. *Acteon scrobiculatus*; Cossmann, p. 1, pl. I, figs. 1-3.

1958. *Acteon scrobiculatus*; Ludbrook, p. 101, pl. 6, fig. 11.

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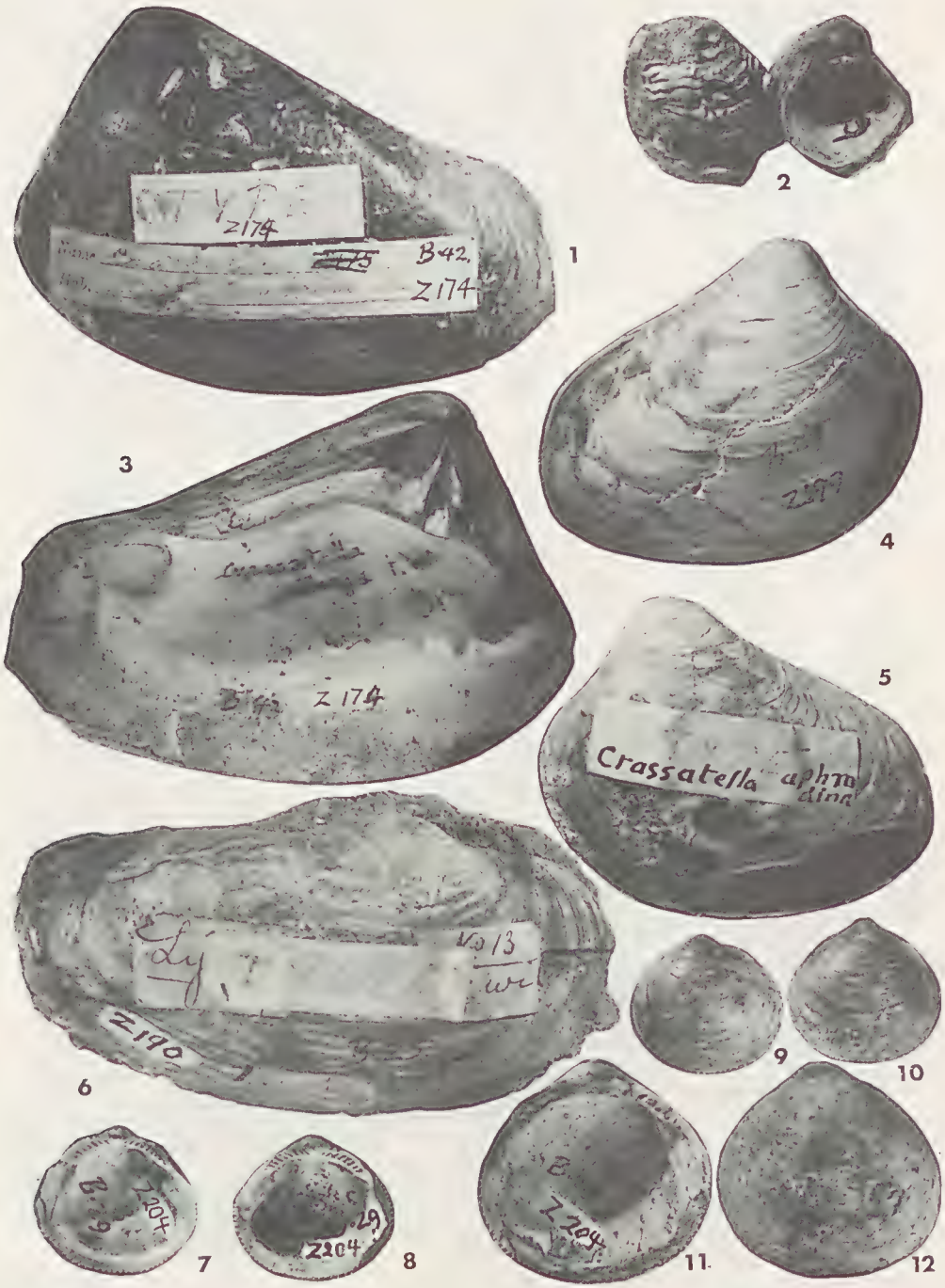
Note.

Since the paper was submitted for publication, Mr. F. L. Sutherland of the Tasmanian Museum has found a shell labelled *Cominella lyraecostatus* T. Woods Plate II, Figure 12, which must be the holotype figured by Tate. The specimen figured herein, Plate 2, Figures 23 and 24, is therefore a paratype.



1, 3.—*Crassatella oblonga* Tenison Woods, Z174.
2.—*Chama lamellifera* Tenison Woods, Z193.
4, 5.—*Crassatella aphrodina* Tenison Woods, Z199.

6.—*Lyonsia agnewi* Tenison Woods, Z190.
7, 8, 9, 10.—*Cuculaea cainozoica* Tenison Woods, Z204, paratype.
11, 12.—*Cucullaea cainozoica* Tenison Woods, Z204, holotype.

1, 2.—*Triton abbotti* Tenison Woods, Z188.
3, 4.—*Typhis maccoyi* Tenison Woods, Z196.
5, 6.—*Natica polita* Tenison Woods, Z206.
7, 8.—*Imperator hudsonianum* Johnston, Z167.
9, 10.—*Cassis sufflatus* Tenison Woods, Z201.
11, 12.—*Natica vixumbilicata* Tenison Woods, Z179.
13, 14.—*Natica wintlei* Tenison Woods, Z197.
15.—*Turbo etheridgei* Tenison Woods, Z202.
16.—*Astralium* (*Calcar*) *ornatissimum* Tenison Woods, Z194.
17.—*Solarium* (*Torinia*) *gibbuloides* Tenison Woods, unnumbered.
18.—*Gibbula crassigranosa* Tenison Woods, B59.
19, 20.—*Thalotia alternata* Tenison Woods, Z168.
21, 22.—*Cominella cancellata* Tenison Woods, Z192.
23, 24.—*Cominella lyracostata* Tenison Woods, Z203 (paratype).
25.—*Gibbula aequisulcata* Tenison Woods, Z175.
26.—*Triton minimum* Tenison Woods, Z189. × 1.3.
27.—*Haurakia crassicosta* May, Z158. × 3.
28.—*Marginella cerpulenta* May, Z160. × 2.5.
29.—*Marginella subquinquidens* May, Z161. × 2.5.
30.—*Marginella atkinsoni* May, Z159. × 2.5.
31.—*Marginella altispira* May, Z162. × 3.
32.—*Rissoina johnstoni* Tenison Woods, Z180. × 5.
33, 34.—*Fusus transenna* Tenison Woods, Z172.
35, 36, 37.—*Crepidula bainsworthi* Johnston, Z165.
38, 39.—*Crepidula umbilicata* Johnston, Z170.
40. *Leda crebrecostata* Tenison Woods, Z178. × 3.
41.—*Nuculana rhomboidea* May, Z182. × 5.
42.—*Turbonilla liraecostata* Tenison Woods, Z210. a, × 4; b, × 5.
43.—*Actaeon scrobiculatus* Tenison Woods, Z211. × 1.5
44.—*Terebra additoides* Tenison Woods, Z200.
45.—*Solecurtus legrandi* Tenison Woods, Z176.
46, 47—*Cardita gracilicostata* Tenison Woods, Z177

1, 2.—*Voluta weldi* Tenison Woods, Z191.
3, 4.—*Voluta stephensi* Tenison Woods, Z183
5, 7.—*Voluta lirata* Johnston, Z185.

6, 8.—*Voluta mortoni* Tate, Z208.
9, 10.—*Voluta stolida* Johnston, Z186.

1, 2.—*Voluta tateana* Johnston, Z187.
3, 4.—*Pleurotoma paracantha* Tenison Woods, Z205.
5, 6.—*Fusus johnstoni* Tenison Woods, Z173.
7, 8.—*Turris altispira* May, B772.
9, 10.—*Voluta pellita* Johnston, Z156.
11, 12.—*Daphnella gracillima* Tenison Woods, Z207.
13, 14.—*Turris conspicua* May, Z157.
15.—*Potamides semicostatum* Tate, B83.
16.—*Terebra simplex* Tenison Woods, B48.

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THE TERTIARY VOLCANIC ROCKS OF FAR NORTH-WESTERN TASMANIA

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(With four text figures, four plates, and two tables.)

ABSTRACT

The Tertiary volcanic rocks of far north-west Tasmania comprise tuffs, pillow-basalts and breccias, entrail basalts, and massive basalts, and eruptions appear to have occurred at several intervals from Lower to Upper Tertiary times. Sea level fluctuations have been important in determining the form assumed by the flows. The lavas were predominantly saturated black glass olivine basalts with one extrusion of undersaturated olivine alkali basalt. The oldest of the volcanics is a widespread formation of sub-aqueously deposited tuffs. These were followed, after a period of erosion, by massive basalts, including a basal zone of entrail lava, which were probably erupted during an Upper Palaeocene-Upper Eocene marine regression. Extensive submarine eruptions followed, resulting in the formation of large cones composed predominantly of pillow breccias. These were probably formed during a marine transgression in the Upper Eocene-Upper Oligocene. A period of erosion, probably subaerial, dissected these cones, and limestones were later deposited on their eroded flanks during a major marine transgression in the Miocene. A final volcanic phase, probably during an Upper Miocene-Pliocene marine regression, saw widespread eruptions of massive basalts, some of which filled valleys eroded in the older volcanics and sediments. The magmatic history of the eruptions in this area appears to be significantly different from that of the Cainozoic volcanics of Victoria.

INTRODUCTION

The dating of the Tertiary volcanic rocks of Tasmania has long been a problem. Banks (1962b) has recognised that basalt eruptions occurred both before and after the deposition of the Middle Tertiary limestones of North-West Tasmania, but the lack of dated Tertiary sediments beneath the older basalts or above the younger basalts has so far precluded more accurate age determinations. Such sediments have not been found by the authors in this area, but both submarine and subaerial Tertiary volcanic rocks occur and it is possible to establish the succession within these rocks and to relate them to the Miocene limestones. The recent stratigraphic work of Bowler (1963), Taylor (1965), and particularly that of Bock and Glenie (1965), has demonstrated and dated several major Tertiary sea level fluctuations in the Bass Strait area. These appear to correlate with the changes from subaerial to submarine volcanism recorded here, but confirmation of the absolute ages of the rocks must await either direct palaeontological or radiometric dating.

Previous Work

Previous descriptions of the geology of parts of the area have been given by Johnston (1888), Ward (1911), Nye and Blake (1938), Edwards (1941a, b, 1950), Nye (1941), Thomas (1945), Gill and Banks (1956), Banks (1957, 1962a, b), Hughes (1957), Gulline (1959), Longman and Matthews (1962), and Quilty (1965, and in press), but this paper represents the first comprehensive study of the Tertiary volcanic rocks.

Location and Access

The area considered comprises a strip, approximately 5 miles wide, of the western coast of far north-western Tasmania, extending south from Woolnorth Point to Greens Creek, about 10 miles south of Temma, and including Trefoil Island. The Trefoil Island-Woolnorth area (Fig. 1, Fig. 2) was mapped during October, 1965, access to the island being gained by light plane from Smithton. On Woolnorth Estate, a vehicular track allows access between Cape Grim and Woolnorth Homestead, from which a private road connects with the Montagu road. The Marrawah-Redpa area (Fig. 3) was visited later in the same month, and also by one of us (K.D.C.) during November, 1966. Marrawah is easily accessible via the Bass Highway. The Temma area (Fig. 4) was visited by one of us (F.L.S.) during September and November, 1964. Access to this area is by vehicular track, usually passable only with four-wheel drive vehicles, with a ferry crossing at the Arthur River.

Physiography

Edwards (1941a) describes the major physiographic features of the Woolnorth and Marrawah areas and recognizes two major divisions, viz., an extensive, low-level coastal plain merging inland

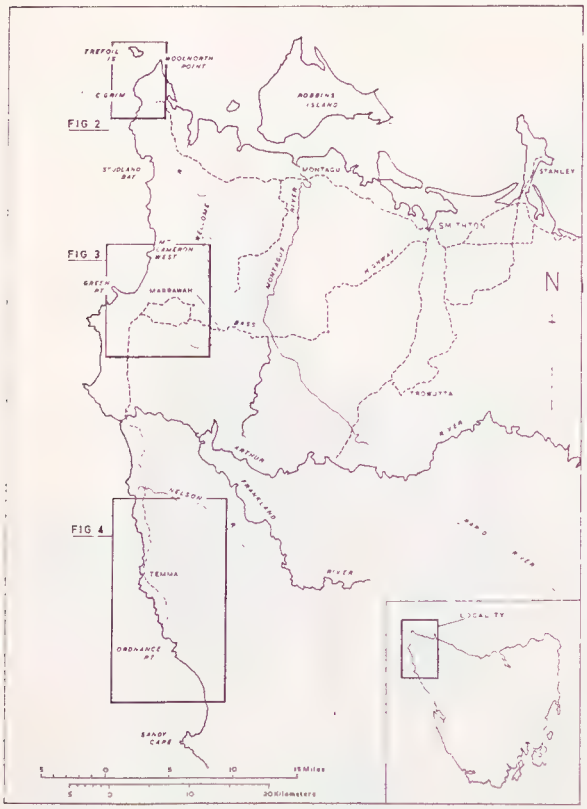

FIG. 1.—Locality map.

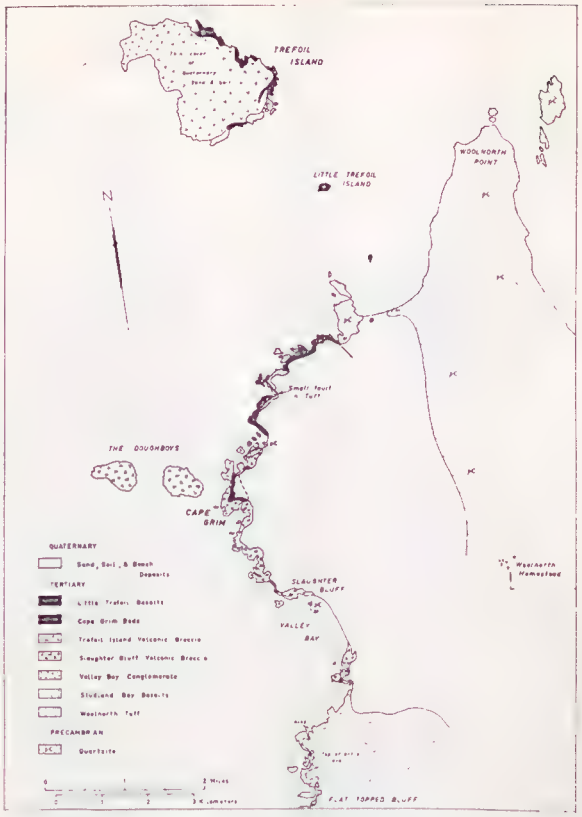

FIG. 2.—Geology of the Trefoil Island-Cape Grim area.

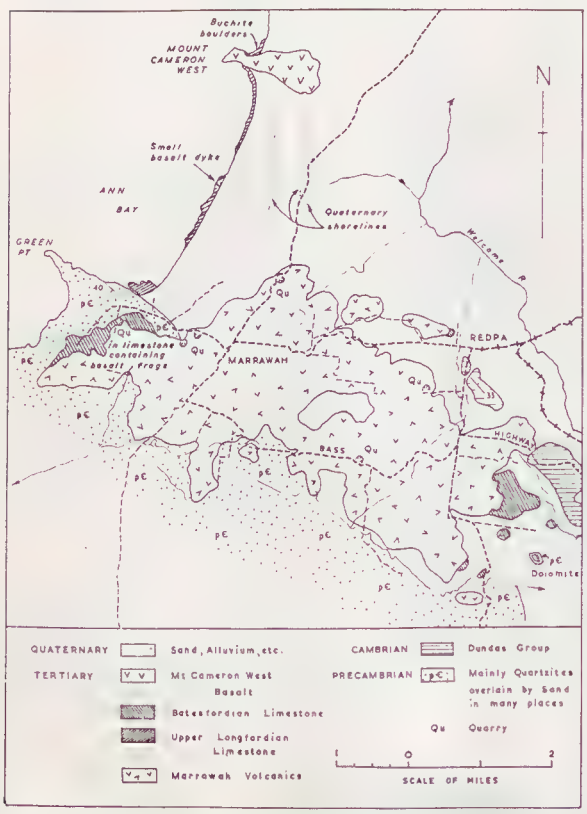

FIG. 3.—Geology of the Marrawah-Redpa area (modified from Gulline, 1959).

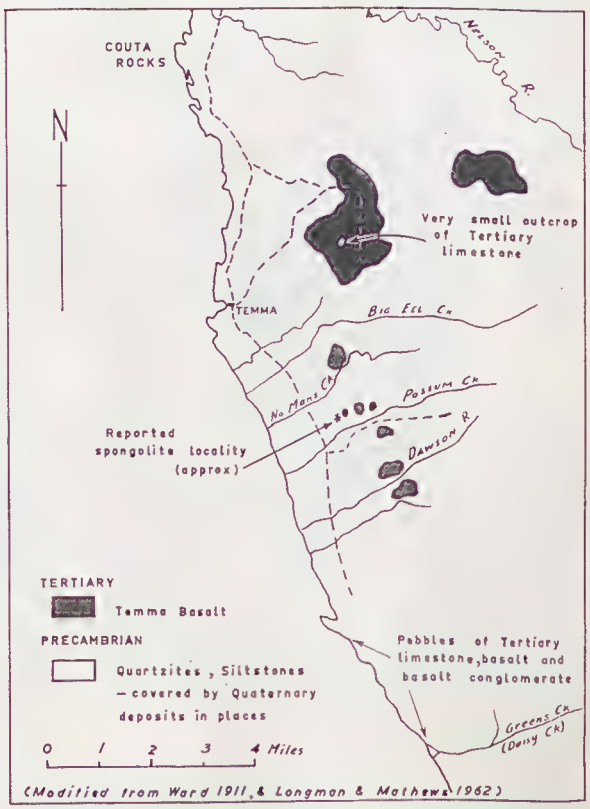

FIG. 4.—Distribution of Tertiary rocks in the Temma area.

into a series of large swamps and covered by Quaternary sand dunes in many coastal areas, and a line of coastal hills ("resumed islands"), including a strip from Woolnorth Point to Studland Bay and the high areas on basaltic rocks around Marrawah. Descriptions of the Quaternary sand ridges in the Marrawah area are also given by Gill and Banks (1956). In the Woolnorth area, outcrops of Tertiary rocks are generally restricted to a narrow coastal strip exposed by wave action, the inland areas being covered by Quaternary soils, sands, gravels and beach deposits.

The physiographic features south of the Marrawah area are dealt with by Ward (1911) and Longman and Matthews (1962). Prominent dunes fringe large stretches of the coast and in places ridges extend inland for about 2 miles. The dunes are associated with a low-lying, and in parts swampy, coastal plain cut in Precambrian mudstones with higher areas of quartzites. The coastal plain is cut in an older erosional surface (The Henty Surface ?) which rises gently inland from about 200 feet above sea-level, and includes the isolated remnants of Tertiary basalt.

STRATIGRAPHY

Basement rocks in the area consist predominantly of Precambrian quartzites. Precambrian dolomite and Cambrian Dundas Group rocks occur south and east of Redpa (Nye, 1941; Gulline, 1959) but these have not been examined. The Tertiary rocks comprise tuffs, pillow breccias, basalts and limestones, and these are described in some detail. Quaternary deposits occur as a superficial cover over many areas. Rock specimens are housed in the collection of the Tasmanian Museum, Hobart, with duplicates of most specimens in the Queen Victoria Museum, Launceston. Specimens of minerals collected from the basalts are housed in the Queen Victoria Museum.

Precambrian Rocks

"Younger" Precambrian rocks form the basement beneath most of the area under consideration. Longman and Matthews (1962) have described these rocks in the Temma-Arthur River area, and Gulline (1959) mentions that Precambrian quartzites occur in the Marrawah and Woolnorth areas, although on general appearance he considered these rocks might be older than the Carbine Group rocks further east (Carey and Scott, 1952).

Bedded and massive quartzites outcrop fairly continuously from Woolnorth Point south to Woolnorth Homestead (Fig. 2), and small isolated outcrops occur at sea level in Valley Bay and just north of Cape Grim. The rocks are folded into broad gentle folds with axes trending north to north-north-east, and dips are low to moderate. The quartzites are pale grey to white, commonly saccharoidal in texture, and cross-bedding and ripple marks are fairly common. Similar quartzites, with some interbedded coarse conglomerates, outcrop on Green Point, near Marrawah (Fig. 3). Here the rocks trend north-west and dip south-west at 30°-60°. Cross-bedding is again abundant, and a large proportion of the bedding surfaces show ripple marks. The ripples vary greatly in form and orientation. Large, four-sided mudcracks (?) also occur.

The age of these quartzites is unknown, but the presence of well-preserved sedimentary structures, the lack of strong deformation, and the presence of dolomite just to the east, suggests correlation with the "Younger" Precambrian Bryant Hill Quartzite (Longman and Matthews, 1962; Gulline, 1959; Carey and Scott, 1952) of the Smithton and Temma areas.

Tertiary Rocks

The probable Tertiary succession is given in Table 1. This table incorporates the major marine transgressions and regressions postulated by Bock and Glenie (1965) from stratigraphic evidence in South-Western Victoria. It is considered that these fluctuations probably also affected north-western Tasmania, and the stratigraphic evidence available seems to support this.

Woolnorth Tuff

The Woolnorth Tuff is that formation of generally flatly bedded vitric tuffs, at least 30 feet thick, outcropping intermittently in shoreline cliffs and platforms between Cape Grim and Woolnorth Point (Fig. 2). It is the oldest formation, apart from the Precambrian, exposed in this area. Similar rocks south of Valley Bay and on Trefoil Island are correlated with this formation. The base of the tuff is nowhere exposed, but would appear to be an unconformity on folded Precambrian quartzites in the type area. The top of the formation is an erosional disconformity, overlain by the Studland Bay Basalts south of Valley Bay, by the Slaughter Bluff Volcanic Breccia in the Cape Grim area, by the Little Trefoil Basalts north of Cape Grim, and by the Trefoil Island Volcanic Breccia and the Little Trefoil Basalts on Trefoil Island. The tuff is considered to be of lower Tertiary age.

The old erosion surface developed on the tuff, as exposed beneath the overlying rocks in a number of places, is in the form of steep cliffs, up to 30 feet or so high, fronted by flat platforms or benches. Some of these platforms are at almost the same level as the present shore platforms. Thus, beneath the Studland Bay Basalt, south of Valley Bay, the old platforms are exposed in places through windows in the basalt on the present shore platforms, while the basalt abuts against and covers old cliffs exposed through vertical erosion windows and in sea caves cut in the present shoreline cliffs (Plate I, Fig. 3). A similar topography exists beneath the Slaughter Bluff Volcanic Breccia and the Little Trefoil Basalts north of Cape Grim. In one place the basalt fills a small undercut cave at the foot of an old cliff, and there are small patches of basalt higher up on the face of the cliff.

The form of the erosion surface is somewhat similar to the present shoreline topography of platforms and cliffs, and the possibility that it represents a former shoreline, at about present sea level, has been considered. However, it is probable that similar features would be developed under most erosional conditions because of the combination of flat bedding, steep joints and faults, and joints parallel to bedding.

Cape Grim area

The best exposures of the Woolnorth Tuff occur

TABLE 1

Proposed Tertiary Succession. Marine phases based on Bock and Glenie, 1965 (*T = Transgression, R = Regression*); *Faunal Units are those of Carter,* 1958.

Marine Phase	Age	Stage (Victorian)	Faunal Unit	Stratigraphic Unit
				? Temma Basalt (?)
				? Little Trefoil Basalts (?)
R	PLIOCENE	KALIMNAN		? Mt. Cameron West Basalt (?)
— — ? — —		MITCHELLIAN CHELTENHAMIAN		
		BAIRNSDALIAN	11	
T		BALCOMBIAN	10	
		BATESFORDIAN	9	
	MIOCENE		8	Marine Limestones
T		LONGFORDIAN	7	
			6	
			5	
R		JANJUKIAN	4	Marrawah Volcanics (?)
	OLIGOCENE			Trefoil Island Volcanics Breccia (?)
			3	? Slaughter Bluff Volcanic Breccia (?)
T	— — — — —	ALDINGAN	2	Valley Bay Conglomerate (?)
			1	
	EOCENE			Studland Bay Basalts (?)
R	— — — — —			Woolnorth Tuff (?)
	PALAEOCENE			
T				

in shoreline cliffs about three-quarters of a mile north of Cape Grim. Here the tuffs are flatly bedded, with an easterly dip of about 4°, except where they are folded adjacent to a small fault (Plate I, Fig. 1). The folding occurs only on the eastern side of the fault and dies out away from it, suggesting that the structures are related, and the nature of the folds suggest deformation while the sediments were more or less unconsolidated. The tuffs show honeycomb weathering, and are fine-grained and well sorted except for rare small quartzite pebbles. The general colour is dull yellowish-brown, while thin bands of slightly finer grained and lighter coloured tuff, 3 to 6 inches apart, produce a prominent banding (Plate I, Fig. 2).

A distinctive feature of the tuffs in this area is the very well developed climbing-ripple lamination (Plate I, Fig. 2). This structure is formed by the downcurrent migration of small ripples under conditions of continuous addition of sediment. The rate and direction of ripple migration in this area indicates a gentle current from approximately south-east. Hills (1965, p. 13) illustrates similar ripple bedding from Pleistocene tuffs in Victoria.

Several small, vertical faults, trending 150° T, affect the tuffs. Displacements are of the order of a few feet or less, although the displacement on the fault associated with the folding is not known. Two sets of vertical joints are also prominent, one parallel to the faults and one at 040° T, and jointing parallel to bedding also occurs.

Near Cape Grim itself the tuffs are exposed on shore platforms, in places covered by a thin veneer of Slaughter Bluff Volcanic Breccia (Plate III, Fig. 5, 6). The tuffs here show slight variations in dip, probably resulting from deposition in small troughs in the basement.

Thin sections of the tuff (T.S. 112, 160*) from

* Numbers refer to the thin section catalogue in the Tasmanian Museum, Hobart.

the type locality show the rock to consist predominantly of glass shards (Plate IV, Fig 1) up to 0.6 mm long but mostly in the range of 0.05-0.2 mm (very fine sand). These constitute about 60-70% of the rock. Each shard has a thin fringe, 0.007-0.01 mm thick, of a birefringent mineral, probably lussatite (a mixture of fibrous chalcedony and opal). The interstices are filled with chalcedony. Rare fragments of olivine and very rare quartz fragments are also present, and these also have lussatite (?) fringes. Many of the shards are pale amber coloured and show very slight birefringence, and these may be palagonite. The fringe of birefringent lussatite (?) gives them a bright outline under crossed nichols (Plate IV, Fig. 1). Vesicles within the glass fragments are also lined with this mineral. That the lussatite (?) was introduced after deposition is evidenced by its presence on the quartz and olivine grains and the thinning or absence of the fringes where grains are in contact.

Valley Bay area

South of Valley Bay there are rare outcrops of tuffs exposed through erosion windows in the Studland Bay Basalts on shore platforms and cliffs. The best exposure is a cliff face between two prominent shoreline caves (Plate I, Fig. 3). Here the tuffs are overlain by " entrail " basalt near the top of the cliff, and the columnar basalt on the shore platform also rests on tuff. The upper contact is very irregular, and a layer of weathered material beneath the " entrail " lava may represent an old soil horizon. The bedding in the tuffs varies from horizontal to almost vertical, and in places is strongly contorted. Cross-bedding is again present, and a number of irregular, sub-vertical clastic dykes, up to 8 inches or so wide and containing angular blocks of tuff, cut through the beds.

A thin section of the tuff from here (113) shows it to consist predominantly of glass shards, up to 0.5 mm long, completely altered to brown palagonite, and cemented by chalcedony.

Trefoil Island

The oldest rocks on Trefoil Island are a series of flatly bedded tuffs exposed on shore platforms and cliffs along the south-eastern coast. The tuffs weather to green and are olive-grey when fresh. They are generally coarser grained than the tuffs in the Woolnorth area, and contain some bands resembling fine agglomerate. Bedding is fairly prominent as an alternation of finer and coarser layers up to 15 inches or so thick. Rare fragments of Precambrian quartzite up to 8 inches long occur in the tuffs, and the coarser layers contain fragments of weathered volcanic material up to several inches across.

The section here is at least 20 feet thick, and the base is not exposed. The tuff is overlain by the Little Trefoil Basalts and by the Trefoil Island Volcanic Breccia. The contact with the latter is not exposed, but appears to be an erosional disconformity since the breccia occurs down to sea level only a short distance from where the tuffs extend to at least 20 feet above sea level. The tuffs are cut by two sets of steep joints, the major one at 145°-165° T, and another at 090°-100° T.

A thin section of the tuff (114) shows it to be more altered than in the Woolnorth area and to be strongly zeolitized. Most of the original glass has been altered to cryptocrystalline quartz, brownish palagonite or clay, although the vesicular nature is still prominent. Many of the fragments and vesicles are fringed with lussatite (?). The large voids and vesicles, particularly in the coarser layers, are mostly lined with a fibrous zeolite, possibly phillipsite, and apophyllite may also be present filling some of the interstices. There are rare fragments of quartz up to 0.25 mm across.

Origin of the tuff

The prominent horizontal bedding, and the presence of cross-bedding and climbing-ripple lamination in the Woolnorth area, indicate that the tuffs were deposited subaqueously. The ripple lamination indicates rapid deposition in an area swept by a gentle current from the south-east. Whether deposition occurred in lakes, lagoons or a shallow sea is not known, but the widespread occurrence of horizontal bedding, the uniformity of the current direction, and the fact that the area was close to the coastline through much of the Tertiary, possibly suggest a submarine environment. The coarser nature of the tuff on Trefoil Island suggests that this area was closer to the source, although there may have been several sources.

Age

The Woolnorth Tuff is older than the Upper Longfordian Cape Grim Beds. It is also older than the Slaughter Bluff Volcanic Breccia, which is considered to be of Upper Eocene-Upper Oligocene age. The erosion surface developed on the tuff was most probably formed subaerially after consolidation, indicating at least a partial marine regression prior to the extrusion of the overlying rocks. This regression possibly corresponds to the Middle Paleocene-Middle Eocene regression recorded from Victoria (Table 1). Thus the tuff is probably not younger than Middle Eocene. The oldest rocks overlying the tuff are the Studland Bay Basalts, which are subaerial and probably extruded during this same regression after dissection of the tuff.

The lower limit for the age of the tuff is not known. The tuff overlies Precambrian quartzite, but is considered to be Lower Tertiary, or possibly Cretaceous, because of the horizontal bedding, the lack of strong induration, the volcanic origin, and the presence of simple jointing similar to that in Lower and Middle Tertiary rocks at Wynyard, the Tamar Valley and other areas.

Studland Bay Basalts

The Studland Bay Basalts are those massive and " entrail " basalts, at least 250 feet thick, exposed along the shoreline between Studland Bay and Valley Bay, and forming Flat Topped Bluff (Fig. 2). The basalts overlie the Woolnorth Tuff and are considered to be older, at least in part, than the Slaughter Bluff Volcanic Breccia. Only their northern extent has been mapped in detail.

The lowermost 50 feet or so of this basalt exhibits a very characteristic form not previously recorded from the Tertiary basalts of Tasmania. The zone can be traced south from Valley Bay for at least a mile, and is overlain by " normal " massive basalt. Several flows may be represented within the zone

TABLE 2

Analyses of basalts from Slaughter Bluff Volcanic Breccia (S.B.V.B.) at Cape Grim and Little Trefoil Basalt (L.T.B.) ½ mile N. of Cape Grim, and chabazite from the Marrawah Volcanics (Chab., M.V.) in quarry 2 miles S.W. of Redpa. Determinations by X-Ray Spectrography (D. I. Groves, Analyst). Na_2O (Chab.) by flame photometry (G. Sanders).

	S.B.V.B.	L.T.B.	(Chab.) M.V.
SiO_2	53.01	49.77	50.29
Al_2O_3	14.46	13.10	21.46
Fe_2O_3/FeO	12.78	13.61	0.36
MgO	6.04	8.82	0.74
CaO	6.87	6.00	4.32
Na_2O	2.70	2.39	4.99
K_2O	1.40	1.36	1.12
MnO	0.19	0.10	0.00
TiO_2	2.25	2.09	0.00
P_2O_5	0.28	0.29	0.02
Ig. Loss	0.76	0.49	15.47
TOTAL	100.74	98.02	98.77

but contacts between flows are not obvious. The basalt consists of a series of overlapping, twisted, more or less tubular bodies, 1 to 4 feet in diameter and up to 8-10 feet long, which commonly show "necking" at their ends. The structures resemble pillows but are elongated and do not show the flattening typical of pillows. The bodies are usually circular but may be oval in cross-section, and generally show a preferential alignment of their long axes (Plate I, Fig. 3, Fig. 5). They show tachylitic margins and radial jointing, and usually have a central vesicle which is commonly mineral-filled. External surfaces are generally rough and cracked, but some show ropy flow structure. Individuals may be moulded against one another to some degree but generally the tubes are not much deformed. This type of basalt grades both laterally and vertically into sections or lenses of massive basalt showing well developed columnar jointing (Plate I, Fig. 4). The proportion of massive basalt within the zone appears to increase to the south.

While the resemblance to pillow lava might suggest a subaqueous origin for this lava, the intimate association with massive basalt and the lack of brecciation indicate that the flows must have been dominantly subaerial. A number of authors have described structures similar to pillows in subaerial pahoehoe-type flows (Cotton, 1944, p. 290). Wentworth and McDonald (1953, p. 35) use the term "entrail pahoehoe", while Rittman (1962, p. 66) describes a similar type of pahoehoe lava, formed under conditions of low pressure and slow rate of flow, and calls it entrail lava. While the term lacks aesthetic appeal, the mode of formation and the structures produced appear to be analogous to those in the Studland Bay Basalts, and the term conveys an excellent impression of the form of the lava.

This lowermost zone of entrail lava overlies the erosion surface previously described in the Woolnorth Tuff, and extends below sea level to the west. An old cliff covered by the basalt has been exhumed just south of Valley Bay (Plate I, Fig. 3). Here the basalt shows vertical cooling columns at the cliff base, nearly horizontal columns against the steep face, and entrail structure over the top.

The entrail basalt is strongly scoriaceous and amygdaloidal in many places, with cavity fillings of calcite, aragonite and chalcedony. Small xenoliths of baked sediment derived from the underlying Woolnorth Tuff are present in places. The zone is overlain by massive basalt with well developed cooling columns, the contact being fairly well defined with no intervening sediments or apparent weathering. This columnar basalt forms a prominent, nearly horizontal horizon, 15 to 20 feet thick, in the cliffs for some distance to the south (Fig. 2). Above this the basalt exposures are poor to the top of Flat Topped Bluff. A lateritized surface may be present on this basalt plateau, as indicated by the extensive areas scattered with pieces of pisolitic ferricrete.

Petrology

A sample collected from the entrail basalt unfortunately was lost, so that a petrological description is not possible at this stage. However, xenolithic (?) blocks of very similar-looking basalt occur in the Slaughter Bluff Volcanic Breccia, and their petrology is described in that section.

Thin sections (115, 116) of massive basalt from the prominent columnar horizon and from near the top of the sequence showed porphyritic olivine basalts with a sub-ophitic groundmass of pyroxene and plagioclase, and a hyaloophitic to intersertal mesostasis. Phenocrystic to granular olivine forms 8-12% of the rocks as corroded subhedral to anhedral crystals up to 2 mm across. The olivine is colourless, fresh in some sections, but largely altered to antigorite in others, and is optically negative with 2V's of about 85°, indicating a composition of about Fo 80-85. The plagioclase (about 40%) is labradorite (about Ab_{45-50}), and forms laths rarely exceeding 1 mm in length. It is sub-ophitically intergrown with anhedral to subhedral augite (25-30%) up to about 0.8 mm. in length. The augite shows pleochroism from pale yellowish to pale violet and is probably titaniferous.

The mesostasis (20-30%) is an opaque black glass with network cracks, grading into areas of brownish-grey glass containing numerous skeletal microlites of pyroxene and feldspar. Iron ore (5%) has largely crystallized as slender rods up to 0.8 mm long and small anhedral grains, mostly restricted to the mesostasis. Small irregular amygdales filled with carbonate are present in some sections. The basalts appear to be saturated "black glass" types (Spry, 1962), with cooling textures related to the Pontville Type (McDougall, 1959).

Origin

The presence of massive basalt within the zone of entrail lava, and the lack of brecciation, indicate subaerial rather than subaqueous conditions for this zone. The very irregular surface over which this early lava flowed may have contributed to the development of the entrail structure, as suggested by Hoffman (1933). However, the possibility of contact with shallow water in places cannot be

excluded. The distribution of the basalt types about the pre-existing cliff (Plate I, Fig. 3) also suggests that the entrail lava was not subaqueous since, if so, it would be expected to occur at the base of the cliff rather than over the top. This distribution also shows that the lava flow lapped against the cliff and built up until the cliff was overtopped, suggesting a source somewhere to the west. This is also indicated by the general orientation of the entrail structures.

There are two possibilities for the origin of the massive basalts which overlie the entrail zone. The clean, level contact between the two suggests the flows were related eruptions, the massive form being the result of flow over the smooth surface formed by the top of the entrail flow. Alternatively, the massive flows may be much younger in age and possibly erupted from a different source.

Age

The Studland Bay Basalts are younger than the erosion surface cut in the Woolnorth Tuff. Boulders of basalt identical to the entrail lava are a dominant constituent of the Valley Bay Conglomerate just to the north (Fig. 2), which is overlain by typical Slaughter Bluff Volcanic Breccia, indicating that both these rocks are younger than the entrail zone at least. The presence of xenolithic (?) blocks of similar basalt in the Slaughter Bluff Volcanic Breccia also indicates this. The extrusion of the entrail lava was most probably subaerial and this, together with the fact that it extends below present sea level, suggests possible correlation with the Middle Palaeocene-Middle Eocene marine regression of Bock and Glenie (1965).

As previously mentioned, the overlying massive flows could represent much younger extrusions, possibly of similar age to the Little Trefoil Basalts (Pliocene ?).

Valley Bay Conglomerate

The Valley Bay Conglomerate is that formation of basaltic boulder conglomerate and sandstone outcropping on the shoreline near the southern end of Valley Bay. The conglomerate appears to lie within the Slaughter Bluff Volcanic Breccia, and is probably transgressive across the contact between the breccia and the Studland Bay Basalts. It is 15-20 feet thick.

Bedding within the formation dips 8° northeast (Plate 2, Fig. 2). The contact with the underlying breccia is poorly defined, the base consisting of a boulder bed which resembles the breccia except for the presence of lenses of sand. This is overlain by several feet of friable sandstone which lenses out up-dip and contains a number of prominent calcite veins parallel to bedding. Following this is a series of interbedded boulder and pebble paraconglomerates and conglomeratic sandstones (Plate II, Fig. 2). Bedding planes are poorly defined and there are considerable lateral variations in lithology. The top of the formation is overlain by a thin flow of pillowy lava (Plate II, Fig. 1) followed by typical Slaughter Bluff Volcanic Breccia.

The conglomerates contain sub-angular to well rounded boulders up to 6 feet across, most being less than 1 foot, in an abundant sandy matrix of weathered volcanic material. The boulders and pebbles are predominantly of basalt, but some consist of volcanic breccia similar to the underlying breccia. The basalt boulders are predominantly of the vesicular amygdaloidal type typical of the entrail zone of the Studland Bay Basalts, which occurs just to the south.

A thin section (117) of a basalt boulder showed a petrology closely similar to that of a xenolithic (?) block of amygdaloidal basalt, also probably derived from the Studland Bay Basalts, in the Slaughter Bluff Volcanic Breccia (q.v.). Some of the boulders are more weathered than others and are reddish in colour, indicating a certain amount of weathering before deposition.

The rocks are affected by two sets of joints, the main one at 150°T, and a second set at 025°T. The joints break through pebbles and boulders in places.

A thin section (118) of a sample from one of the sandy layers shows the rock to consist of altered brownish fragments, fragments of "black glass" basalt, isolated feldspar laths, quartz fragments and small patches of fibrous zeolite, bonded mainly by authigenic fibrous chalcedony-opal (lussatite ?). There is very little clay except in the cores of some of the weathered fragments. The brownish fragments are commonly vesicular and are composed of a mixture of cryptocrystalline quartz, palagonite, chalcedony, opal and clay, and probably represent altered glassy material. The basalt fragments are sub-angular to rounded and up to 2 mm long, and vary from slightly altered to strongly decomposed.

Origin

The presence in the conglomerate of very large boulders of local rock types indicates very little transport for these. The lack of cross-bedding or cut-and-fill structures, the very poor sorting, and the local derivation suggest the formation is not of fluvial origin, while the poor sorting and the angularity of many of the boulders are not suggestive of a beach deposit. The combination of large basalt boulders and abundant basaltic sand could be formed near the base of marine cliffs, with large fragments of basalt, already partly rounded by chemical weathering, being shed and covered with sand derived from the adjacent weathered basalt terrain.

Age

The Valley Bay Conglomerate is "interbedded" with the Slaughter Bluff Volcanic Breccia near the base of the latter. It probably represents the deposits associated with a shoreline during the early stages of the marine transgression during which the breccia was formed. This transgression possibly correlates with the Upper Eocene-Upper Oligocene transgression indicated by the work of Bock and Glenie (1965).

Slaughter Bluff Volcanic Breccia

The Slaughter Bluff Volcanic Breccia is that succession of bedded basaltic pillow breccias and associated small lava flows outcropping in shoreline cliffs and platforms in the Valley Bay-Slaughter Bluff-Cape Grim area. The breccia disconformably overlies the Woolnorth Tuff, is "inter-

bedded" with the Valley Bay Conglomerate near its southern limit, and is disconformably overlain by the Upper Longfordian Cape Grim Beds. Its maximum thickness cannot be estimated from available outcrops, but must be considerably in excess of 300 feet and is possibly several thousand feet.

General Description

The breccia is a crudely bedded, darkish, very rough textured rock consisting dominantly of angular basaltic fragments in a finer grained matrix, but also contains numerous isolated pillow-like bodies and some small flows of pillowy lava. It outcrops as bold coastal cliffs up to several hundred feet high, and also constitutes the two small islands off Cape Grim known as the Doughboys. An old erosion surface cut in the Woolnorth Tuff is preserved under the breccia north of Cape Grim (Plate III, Figs. 5, 6). Elsewhere the breccia extends below sea level, although small fragments of tuff are present within the breccia at the base of Cape Grim. At its southernmost exposure it is "interbedded" with the Valley Bay Conglomerate (q.v.), and at Cape Grim it is overlain disconformably by the Cape Grim Beds (Plate II, Fig. 4).

Large-scale bedding is prominent in nearly all cliff outcrops of the breccia (Plate II, Figs 3, 4) but is generally not distinguishable across the shore platforms. The beds dip generally north-easterly and dips range from 15° to 45°, 30° being the most common. As the bedding in the underlying Woolnorth Tuff remains essentially horizontal, the dips in the breccia probably represent the original depositional slopes. Bedding thicknesses range from 4 to 30 feet, most units being 10 to 20 feet thick. Large-scale "cross-bedding" is visible on the south-eastern side of Cape Grim (Plate II, Fig. 4).

The proportions of fragments and pillows vary considerably within and between beds. On the southern point of Cape Grim the lowermost unit, about 40 feet thick, is rich in pillows (Plate II, Fig. 3) and contains several small flows of pillowy lava (Plate III, Fig. 1). The upper 10 feet of this unit consists largely of basalt fragments with some isolated pillows. The next bed, about 15 feet thick, also consists mostly of angular fragments but with rare pillows and large pillow fragments. Higher still a bed was noted in which the matrix was the dominant constituent (Plate III, Fig. 2). The general colour of the breccia is dark grey, but the upper parts of some layers are distinctly lighter coloured, being almost orange-yellow (Plate II, Fig. 3). This suggests some surface alteration before deposition of the overlying unit.

In places the breccia shows continuous narrow zones of highly altered material, a foot or so wide, which appear to follow joints and are more or less parallel to bedding.

The constituents of the breccia are of four types, viz., fragments, isolated pillow-like bodies, small lava flows, and the matrix.

Fragments

These are up to several feet long, but mostly less than 1 foot, angular and randomly arranged in the matrix. Many show a chilled margin, sometimes with flow structure, on one side only (Plate II, Fig. 6), indicating that they are fragments of broken-up pillow-like bodies. Other evidence also indicates that the breccia was formed mainly by the breaking up of lava flows similar to the small flows still preserved. Most of the fragments consist of moderately vesiculated, dark coloured basalt, with a well developed tachylitic cooling margin. Some show thick double or multiple cooling crusts (Plate II, Fig. 6), giving them a banded appearance.

Associated with the normal basaltic fragments are rare fragments of very vesicular amygdaloidal basalt, up to 8 feet long, with carbonate cavity fillings (Plate III, Fig. 2). These blocks contrast markedly with the surrounding fragments and are more common in some layers than others. They do not show the well developed cooling crusts typical of the other fragments, and no recognizable pillows of this type of basalt were seen, suggesting they may have a slightly different origin.

Isolated pillow-like bodies

These are oval to circular in cross-section and mostly show radial jointing. A large central vesicle is usually present, in some cases filled with minerals. The pillows are up to 6 feet or so long, most being 2 to 5 feet in length and 1 to 3 feet in diameter. Partially broken examples also occur (Plate II, Fig. 5). Some of the bodies are roughly cylindrical and resemble portions of the entrail lava previously described from the Studland Bay Basalts. The outer surfaces are rough and cracked, and some show ropy flow structure. The majority of the bodies are isolated, and in some cases the break-off area can be seen (Plate II, Fig. 5). There are also examples of several bodies interconnected by narrow waists.

Minerals collected from the central vesicles include calcite, aragonite, chalcedony, zeolite (phillipsite ?), apophyllite, and hydrated calcium silicates.

Small lava flows

The greatest concentration of these appears to be in the lowermost layers exposed around the foreshore of Cape Grim, and a good example occurs overlying the Valley Bay Conglomerate (Plate II, Fig. 1). The flows are up to 40 feet wide and 10 feet thick. They have a very characteristic appearance, consisting of a series of interconnected and in places anastomosing tubules, tongues, pillows and entrail-like structures which wrap around and lie in contact with one another but which are, for the most part, separated by their individual cooling crusts (Plate 3, Fig. 1). Some of the flows are quite similar to parts of the entrail lava previously described in the Studland Bay Basalts.

Matrix

The matrix of the breccia consists of small, angular, tachylitic fragments, less than one inch across, with abundant calcite and aragonite distributed as blebs, veins and radiating masses. It strongly resembles the palagonitic matrix of the Trefoil Island Volcanic Breccia (Plate I, Fig. 6; Plate IV, Fig. 2) and likewise weathers readily.

Petrology

Thin sections of the normal basalt forming

blocks and pillows showed little petrological variation. Sections 119, 120, 121 and 122 contain olivine and pyroxene phenocrysts and microphenocrysts, plagioclase laths and pyroxene grains, set in a groundmass of black glass with a hyaloophitic texture. The olivine and pyroxene phenocrysts tend to be glomeroporphyritic and in some cases the pyroxenes group around a nucleus of olivine crystals. The olivine forms 8-12% of the rock as crystals ranging up to 3 mm across, some with euhedral outlines and some showing corrosion. It is chrysolite with 2V's close to 90° and negative optical sign, rarely encloses small pyroxene grains, and is commonly partly or completely altered to serpentine, mainly antigorite. The pyroxene phenocrysts form less than 5% of the rock and range up to 1.8 mm across. The pyroxene is a pale grey augite, and the larger phenocrysts generally consist of several "welded" plates about 0.4 to 1.0 mm across. Some of the smaller phenocrystic pyroxene and olivine is subophitically intergrown with plagioclase laths.

The plagioclase is a labradorite of composition about Ab_{40}-Ab_{36}. It shows zoning, combined albite, Carlsbad and pericline twinning, and ranges from microlites to phenocrystic laths up to 1.5 mm in length with a tendency to flow alignment. A few of the crystals show corroded cores. In some sections small feldspars are crowded into rare segregations or veinlets 0.5 mm wide. Pyroxene granules (15-20%), usually less than 0.3 mm across, are scattered in the groundmass, tending to form clustered groups and rarely small segregations. The mesostasis of the rock is an opaque black glass forming 30-40% of the rock. It is altered to a greenish serpentinitic clay (?) in places, and contains small amygdales filled with clay and chalcedony. One section (120) showed a corroded quartz xenolith, 1 mm long, outgrown with prisms of clino-pyroxene up to 0.1 mm long. The basalts are saturated black glass types related to the Bridgewater type (Edwards, 1950; McDougall, 1959) but differing in the presence of pyroxene phenocrysts.

Thin sections (123, 124) of basalt samples from the breccia underlying the Valley Bay Conglomerate, although similar to those just described from the breccia above the conglomerate, show some differences. The olivine is generally less altered, no pyroxene phenocrysts were observed, and a little carbonate is present in the groundmass. Corroded quartzite xenoliths with reaction rims of prismatic clino-pyroxene are present. One partially fused feldspar (?) xenolith was observed (section 124) showing development of sillimanite or mullite (?) as felted fibrous masses wrapped around the unfused remnants in a colourless glass. Small isolated needles of the sillimanite (?) were also present within the feldspar remnants.

A thin section (125) of a sample of the amygdaloidal basalt forming xenolithic (?) blocks in the breccia at Cape Grim showed a somewhat weathered basalt containing phenocrysts of olivine, up to 2 mm across, completely altered to serpentine and carbonate. There are no pyroxene phenocrysts. The feldspar is plagioclase, about Ab_{40}, and forms numerous laths and anhedral plates ranging up to 0.8 mm long. The pyroxene occurs as pale coloured augite grains rarely greater than 0.2 mm across, and tends to be intergranular but is also subophitically intergrown with, and poikilitically enclosed by, the feldspar. The rock is a saturated black glass basalt with a texture resembling the Jordan type of McDougall (1959).

A chemical analysis of a basalt sample from Cape Grim (section 120) is given in Table 2. It resembles previously reported analyses of Tasmanian Tertiary black glass basalts (Edwards, 1950; Spry, 1962) but is slightly higher in silica and slightly lower in lime and magnesia.

Origin

The dips measured in the breccia range from 15° to 45° and vary from northerly to easterly. Similar dips appear to be present on the Doughboys. The dips show little sign of closure along the 2 miles of coastal outcrop, suggesting that the breccia originated from eruptions along a north-west trending fissure offshore from the present coast. The large-scale "cross-bedding" at Cape Grim may have originated by transfer of the point of origin of the material to a different position along the fissure.

The breccia, with its pillow-like bodies and pillow fragments in a glassy fragmental matrix, strongly resembles the hyaloclastite pillow breccias formed by subaqueous volcanic activity (Rittman, 1962; Honnorez, 1963; Silvestri, 1963; Sturiale, 1963; Solomon, 1964; and others). The prominent bedding and the uniform dips, the complete lack of any massive basalts within the breccias, the very thick chilled margins on many of the pillows and fragments, and the lack of pyroclastic bombs, also point to a subaqueous origin, while the thickness and wide areal extent of the breccias indicate the eruptions were submarine rather than beneath a freshwater lake.

The alternative theory of origin, that of subarial eruptions, is difficult to justify. Although various authors have considered it possible for pillow-type basalts to form under subaerial conditions (Lewis, 1914; Hoffman, 1933; Stark, 1938), it is generally conceded that pillow breccias must be subaqueous because of the rapid chilling involved (Rittman, 1962; &c.). Hoffman (1933, p. 194) attributes "cross-bedded" pillow breccias in the Columbia River basalts to the breaking up of subaerial pillow lavas, due to flow over an uneven surface, and deposition of the breccia over the end of the flow, producing layers resembling delta foresets. While this mechanism may be possible, the phenomenon has not been observed in nature, and it is extremely doubtful if it could account for the thicknesses observed in the Slaughter Bluff Volcanic Breccia.

The origin postulated by the authors is of a series of submarine eruptions along a northwest fissure with its northern end located not far west of the Doughboys. The earliest lava flows must have been quickly chilled and immobilized, possibly blocking the vent with an initial hyaloclastite breccia (Silvestri, 1963). Further flows would be extruded through this crust to form pillow lava and breccia on contact with seawater, and a linear cone would be built up with steepening slopes. The stable slope angle would eventually become the angle of repose of the breccia material in seawater. The increase in slope would substantially contribute to

the brecciation of the lava because of the gravitational effect. Thus each of the beds or layers of breccia possibly represents a broken-up lava flow deposited on part of the slope of the cone.

In thick flows it seems possible that patches of the pillow lava within the flow or near its base could be carried down the slope within the breccia mass and come to rest before being brecciated. This would explain the isolated flow remnants observed within the breccia in several places. Alteration and "weathering" by seawater between eruptions probably accounts for the lighter colour of the upper surfaces of many of the beds, while the altered zones along joints roughly parallel to bedding may represent slip surfaces of small submarine landslides.

The blocks of scoriaceous amygdaloidal basalt within the breccia do not show the thick chilled margins or the pillow forms of the normal basalt, and are probably xenolithic. The only similar basalt observed is the entrail lava of the Studland Bay Basalts, and the blocks possibly represent fragments of this basalt torn off from the vent and deposited with the breccia.

Age

The Slaughter Bluff Volcanic Breccia is overlain disconformably by the Upper Longfordian Cape Grim Beds. Evidence will be presented (see Cape Grim Beds) that this disconformity probably represents a period of subaerial erosion between the time of formation of the breccia and the marine transgression during which the Cape Grim Beds were deposited. This period possibly correlates with the marine regression recorded by Bock and Glenie (1965) in the Upper Oligocene of south-western Victoria (Table 1). Thus the breccia was probably formed during an earlier marine transgression, possibly the Upper Eocene-Upper Oligocene one of Bock and Glenie. The fact that the breccia rests on an erosion surface cut in the Woolnorth Tuff, which is considered to be Lower Tertiary, supports this. Volcanic activity is recorded in both the lower and upper parts of the Oligocene in the Bass Strait succession (Esso Exploration Australia, Inc., 1966). This includes an Upper Oligocene "tuffite" cone which may be approximately contemporaneous with the Slaughter Bluff Volcanic Breccia cone in age.

Trefoil Island Volcanic Breccia

The Trefoil Island Volcanic Breccia is that basaltic pillow breccia, at least 200 feet thick, which constitutes most of Trefoil Island and is best exposed in cliffs and short platforms around the island. It disconformably overlies the Woolnorth Tuff and is overlain by the Little Trefoil Basalts. Over much of the island the breccia is covered with Quaternary sands and soils.

The contact with the Woolnorth Tuff is not exposed but would appear to be an erosional disconformity. Around much of the eastern half of the island the breccia is overlain by the massive Little Trefoil Basalt. The contact between the two is very irregular, indicating considerable erosion prior to the eruptions of the younger basalt.

The breccia is generally similar to the Slaughter Bluff Volcanic Breccia but has less prominent bedding, fewer isolated pillows and pillowy flows, and lacks the xenolithic (?) blocks of amygdaloidal basalt. Bedding is generally difficult to distinguish, but on the south side of the island rough layering dips about 25°-30° west. These are probably original dips, since the bedding in the underlying Woolnorth Tuff is horizontal. Rare thin lava flows occur within the breccia in places, some showing pillow structure. For the most part the breccia consists of about 40% basaltic blocks in a fragmentary matrix. The blocks range from a few inches to a few feet across and show tachylitic margins. Isolated pillow-like bodies also occur. These have oval to round cross-sections, some being flattened on one side, and show radial jointing and commonly a large central vesicle filled with calcite and aragonite (Plate I, Fig. 6). The matrix of the breccia consists of angular, randomly assorted, tachylitic fragments, ranging up to an inch in size, set in an abundant lime carbonate cement with seams of gypsum (Plate IV, Fig. 2).

Petrology

A thin section (126) of a block showed a porphyritic basalt, with a hyaloophitic groundmass, containing olivine phenocrysts and feldspar laths set in a black glass forming almost half the rock. The olivine (10-15%) is chrysolite, with 2V's close to 90°, and occurs as grains and phenocrysts ranging up to 2.5 mm across, many with euhedral to subhedral outlines. The phenocrysts tend to be glomeroporphyritic, partly or mostly altered to antigorite and generally corroded, with some enclosed patches of glassy groundmass. The feldspar (about 40%) is labradorite, of composition about Ab_{45}, and forms laths, rhombs and microlites up to 0.9 mm long. The black glass of the groundmass is altered in places to greenish-brown nontronite (?), and contains rare vesicles filled with chalcedony. The rock is a saturated black glass olivine basalt with a cooling texture related to the Ouse and Bridgewater types (Edwards, 1950, McDougall, 1959).

A section (127) of the breccia matrix shows that many of the fragments have concave margins (Plate IV, Fig. 2). The tachylite consists of pale yellow glass, probably palagonite, containing crystals of olivine and laths, rhombs and microlites of feldspar. Some of the crystals are truncated at the margins of the fragments. The olivine varies from minute grains up to phenocrysts over 2 mm across that tend to be glomeroporphyritic. The proportion of olivine differs between fragments, being almost absent from many of the smaller fragments and making up about 15% of the largest fragments. Some of the olivines are euhedral, others are strongly corroded, and some contain inclusions of dark glass in contrast with the pale glass of the groundmass. The olivine is chrysolite, with 2V's close to 90° and negative optical sign, and is generally unaltered. The feldspar is labradorite, and forms about 30% of the tachylite fragments, in laths rarely exceeding 0.5 mm in length.

Many of the tachylite fragments contain infilled vesicles up to 3 mm across. Most of these are fringed with layers of greenish opal and lussatite (?) and filled with opal, chalcedony, aragonite, calcite, analcime and nontronite (?), either separately or in combination. The tachylite glass shows darker, brownish areas, particularly around vesicles and on the outer margins of fragments.

A cement of granular calcite, enclosing nests of gypsum plates ringed with clusters of radiating aragonite, separates the tachylite fragments by widths of up to 2 mm. The tachylite of the matrix appears to represent a palagonitised and more quickly chilled phase of the hyaloophitic basalt forming the blocks and pillows in the breccia.

Origin and age

The distinct similarity to the hyaloclastite pillow breccias described in the literature, and to the Slaughter Bluff Volcanic Breccia, suggests a similar origin, from submarine eruptions, for the Trefoil Island Volcanic Breccia. The westerly dip suggests the source was somewhere east of the island.

The age of the breccia is difficult to establish. It is younger than the Woolnorth Tuff (Middle Palaeocene-Middle Eocene ?) and older than the Little Trefoil Basalts (Pliocene ?), and possibly corresponds approximately in age with the Slaughter Bluff Volcanic Breccia (Upper Eocene-Upper Oligocene?). Volcanic activity forming "tuffite" cones is recorded in the Bass Strait succession in the Upper Oligocene and Lower Miocene (Esso Exploration Australia, Inc., 1966) and is possibly related to that forming the Trefoil Island Volcanic Breccia.

Marrawah Volcanics

The Marrawah Volcanics are those basaltic breccias, pillow breccias, and associated lava flows outcropping in the Marrawah-Redpa area. Their distribution is shown in Fig. 3. The volcanics overlie "Younger" Precambrian rocks and are disconformably overlain by Miocene limestones. The thickness of the volcanics is unknown, but is at least several hundred feet.

A 15-foot section of the volcanics is exposed in a quarry about one mile north of Marrawah along the old sand road to Montagu (Fig. 3). Here the rock consists of basalt fragments in a weathered matrix, with no obvious layering or grading. The fragments vary in size but are generally less than 2 feet across, and form about 65% of the rock. They show tachylitic margins up to several inches thick, passing inwards to a coarser grained, generally more decomposed centre. Most of the fragments are angular. In marked contrast with the majority of the fragments are rare blocks of scoriaceous and amygdaloidal basalt. The largest of these is 7 feet long and 5 feet high, showing chilled margins and a large crack, also with chilled edges, extending from the base towards the centre.

A large quarry on the Marrawah Beach road exposes a section of the volcanics 200 feet wide and 80 feet high. The rock here shows crude layering dipping 10°-15° south-west (Plate III, Fig. 3). The rock is dominantly pillow breccia, consisting of 10-20% of blocks and pillow-like bodies, up to 2 feet across, in a finer grained fragmentary matrix. Some of the layers contain up to 75% blocks and pillows. Parts of the breccia are rich in elongate pillows up to at least 8 feet in length, with subcircular to flattened, lens-shaped cross-sections. These show chilled tachylitic margins and many have a central vesicle filled with lime carbonate minerals. Some of the blocks show chilled margins on one side only, indicating that they were derived from broken-up pillows. The matrix of the breccia consists of angular tachylitic palagonitised (?) fragments, up to 1-2 inches across, mixed with abundant calcium carbonate, and is somewhat weathered.

The freshest exposure is in a quarry on the north side of the Bass Highway about 2 miles south-west of Redpa (Fig. 3). The breccia here is similar to that just described but contains some fragments of scoriaceous amygdaloidal basalt. Thin massive basalts are interbedded with the breccias, and both dip 25°-30° west (Plate III, Fig. 4). The massive basalts are up to 4 feet thick, have ropy flow structure on some of the margins, and are closely and irregularly jointed. Patches of pillow lava up to 50 feet wide are also present, and appear to occupy channels in the breccia. This may have been caused by displacement of the unconsolidated breccia material by the more dense pillow lava flowing down the slope.

A feature of the breccia in the above quarry is the presence of abundant white minerals as cavity linings and fillings and as an inter-fragmental cement. These contrast markedly with the dark tachylitic basalt fragments, some of which contain large vesicles up to a foot across in which large, well-formed crystals have grown. Minerals identified by X-ray powder patterns and other means include apophyllite, chabazite, natrolite, tacharanite and its breakdown products tobermorite and gyrolite, calcite, opal, and nontronite. The chabazite has a different habit to that normally found in the Tasmanian Tertiary basalts, occurring as crystals of hexagonal aspect similar to that figured by Dana (1957, Fig. 979) for gmelinite. A chemical analysis (Table 2) shows that it is a soda-rich chabazite, containing over four times the amount of soda in the normal Tasmanian chabazites (authors' unpublished analyses). It is interesting to note that soda-rich hexagonal chabazite crystals (herschelite) are also described from palagonitic basalt in Catania, Sicily (Deer, Howie, and Zussman, 1963, p. 395).

Pillow breccias are also exposed in a quarry near Redpa (Fig. 3). The rock here is strongly weathered and was not examined in detail. Other examples of massive basalts within the Marrawah Volcanics were observed in road cuts about one mile east of Marrawah along the Marrawah-Redpa road, and in a small quarry in a paddock about one-quarter of a mile south-west of the large quarry on the Marrawah Beach road. Close and irregular jointing appears to be characteristic of these massive basalts.

Petrology

Most of the basalts sampled from the Marrawah Volcanics, both from the breccias and the massive flows (thin sections 129, 130) are olivine basalts with a dark, glassy, hyaloophitic-textured groundmass, related to the Ouse and Bridgewater Types of Edwards (1950) and McDougall (1959). Chrysolitic olivine (10-15%) forms corroded, glomerophorphyritic, euhedral to anhedral crystals up to 2 mm across, with some alteration to antigorite. The plagioclase (30-40%) has a composition of about Ab_{65}, and ranges from microlites up to phenocrystic laths 1.5 mm long. Augite occurs as granular to prismatic microlites in the mesostasis, and as small grains, rarely exceeding 0.3 mm in length, in

places forming small segregations. The mesostasis (30-50%) varies from a hylaoophitic to almost intersertal black glass base, and includes numerous microlites of iron ore which, in places, show parallel orientation. Greenish chalcedony usually occurs scattered through the rock filling small vesicles.

These rocks generally resemble the basalts in the similar Trefoil Island and Slaughter Bluff Volcanic Breccias, but appear to lack the phenocrystic pyroxene found in the latter. Some variations in rock types are present in the Marrawah Volcanics which were not observed in the other breccias, and these are described below.

A thin section (132) of the massive basalt from the quarry 2 miles south-west of Redpa is notable for the flow alignment of the feldspars. These wrap around glomeroporphyritic phenocrysts of chrysolitic olivine (8%) up to 2 mm. across. The feldspar (45%) is plagioclase, about Ab_{45}, and the laths range up to 1 mm. Small olivine grains are subophitically intergrown with the feldspar laths, and purplish, pleochroic, titaniferous augite (20%) forms intergranular grains, slender prisms and microlites up to about 0.5 mm long. The mesostasis is an intersertal greyish glass containing granules and rods of iron ore and anhedral plates of feldspar subophitically intergrown with, or poikilitically enclosing, the pyroxene and iron ore. Greenish chalcedony fills small vesicles. The rock is related in texture to the Jordon Type of McDougall (1959).

A section (128) of a basalt sample from the breccia quarry on the sand road to Montagu shows an olivine basalt with phenocrysts of olivine and feldspar set in an extremely fine-grained crystalline groundmass which supersedes the usual glassy mesostasis. Chrysolitic olivine (15%) is glomeroporphyritic and forms euhedral and anhedral grains up to 1.2 mm across, some showing corrosion and most being partly altered to antigorite. The feldspar phenocrysts (30%) form laths up to 1.2 mm long and have a composition of about Ab_{45}. The groundmass consists of numerous minute needles and grains of colourless augite, feldspar and iron ore, rarely exceeding 0.2 mm and mostly less than 0.1 mm. Some of the feldspar phenocrysts, particularly the smaller and presumably later ones, have their edges intergrown with the groundmass constituents. Small clearer areas, poikilitically including groundmass grains, are filled with pale yellow-green chalcedony (?).

The massive basalt from the quarry one-quarter of a mile south-west of the quarry on the Marrawah Beach Road, in thin section (131) proved to be an olivine limburgite. There are numerous small, glomeroporphyritic phenocrysts of olivine (about 15%) averaging about 0.2 mm across, but ranging up to 0.5 mm. Outlines are euhedral to anhedral, some showing corrosion, and the olivine is mostly unaltered. Pyroxene (30%), probably augite, occurs as pale greenish prisms and microlites mostly less than 0.1 mm long and in places clustered into small segregations. These constituents, with small grains of iron ore (5%), are set in a reddish-brown glassy base that forms from one-third to almost one-half of the rock. Small rounded amygdales up to 0.4 mm across are scattered through the groundmass and are filled with yellowish chalcedony, in some cases with a carbonate core.

Origin

The presence of pillows and pillow fragments within the breccias, and the similarity to the Trefoil Island and Slaughter Bluff Volcanic Breccias, strongly suggest a submarine origin for the Marrawah Volcanics. The few dips observable are westerly, suggesting a source somewhere east of Marrawah, possibly located on a major northwesterly fault line mapped to the south by Longman and Matthews (1962). The extension of this fault would pass somewhere between Marrawah and Redpa.

Age

The Marrawah Volcanics are overlain disconformably by Batesfordian limestone, as is discussed under Miocene Marine Sediments, indicating a period of strong erosion, probably subaerial, prior to the marine transgression during which the limestone was deposited. The relationship is analogous to that between the Slaughter Bluff Volcanic Breccia and the Cape Grim Beds. The lower limit to the age of the volcanics is not known but it is suggested that they probably correspond approximately in age with the Slaughter Bluff Volcanic Breccia (Upper Eocene-Upper Oligocene ?) because of the similar environment of formation and the similar relationship to the limestone.

Miocene Marine Sediments

Miocene marine sediments occur in a number of places around North-West Tasmania (Banks, 1962a) and provide the only presently available means of directly dating the associated volcanic rocks. Upper Longfordian sediments occur up to about 150 feet above sea level at Cape Grim and near sea level around Mt. Cameron West and at Green Point near Marrawah. Batesfordian sediments occur between about 130 feet and 300 feet above sea level in the Marrawah-Redpa area and near Temma (?). The contact between the Longfordian and Batesfordian sediments is not exposed, but it seems likely that continuous deposition is represented. Brief descriptions of these rocks will be given only to show their relationship to the volcanic rocks.

Cape Grim Beds

The Cape Grim Beds are those breccias, conglomerates and fossiliferous calcarenites outcropping in cliffs on the northern and eastern sides of Cape Grim (Fig. 2). The beds disconformably overlie the Slaughter Bluff Volcanic Breccia and are overlain by a small outcrop of massive basalt correlated with the Little Trefoil Basalts. The succession is approximately 150 feet thick and is considered by Quilty (1965, and in press) to be Upper Longfordian in age (Faunal Units 7, 8 of Carter, 1958) on the basis of the foraminifera

The sediments occupy a north-trending channel cut in the Slaughter Bluff Volcanic Breccia, probably near the eastern perimeter of the original volcanic cone. The channel is approximately 300 feet wide and 150 feet deep, and its base slopes northwards from about 100 feet above sea level on the east side of Cape Grim (Plate II, Fig. 4) to below sea level just north of Cape Grim. That this slope is not the result of later tilting is indicated by the fact that the bedding in the Woolnorth Tuff, which underlies the breccia is horizontal or dips very slightly east.

The base of the sediments is difficult to define, consisting of coarse talus-type material grading downwards into typical volcanic breccia and upwards into conglomerate containing sub-angular to rounded basalt boulders. On the western side of the channel these basal beds conform roughly to the steep dip slope of the underlying volcanic breccia, but show downward thickening towards the base of the channel. The bedding in the overlying limestones is sub-parallel to the sides of the channel as viewed in transverse section (Plate II, Fig. 4), but the dips become flatter upwards as seen in longitudinal section, north of Cape Grim. This also suggests that the beds were deposited in a sloping channel.

The mode of origin of this channel, whether by submarine or subaerial erosion, is of some importance in determining the age of the Slaughter Bluff Volcanic Breccia. The fact that the channel is sloping suggests that submarine or tidal currents were not responsible. Also, the presence of conglomerate at the base of the Cape Grim Beds indicates either current or wave action, suggesting that the volcanic cone was either partly or completely emergent at some time prior to the marine transgression during which the limestones were deposited.

Thus there is some evidence for a marine regression between the time of formation of the Slaughter Bluff Volcanic Breccia and the major marine transgression in which the Upper Longfordian Cape Grim Beds were deposited. Such a regression can possibly be correlated with the Upper Oligocene-Lower Miocene regression indicated elsewhere in Bass Strait (Bock and Glenie, 1965, Esso Exploration Australia Inc., 1966).

Mt. Cameron West-Marrawah-Redpa area

Flatly bedded limestones are exposed in the intertidal zone along much of the shoreline of Ann Bay and also just north of Mt. Cameron West (Fig. 3). At Mt. Cameron West the beds are at least 30 feet thick and are overlain disconformably by the Mt. Cameron West Basalt (Gill and Banks, 1956). Quilty (in press) assigns these beds an Upper Longfordian age (Faunal Units 7, 8 of Carter, 1958) on the basis of the foraminifera, and correlates them with the Cape Grim Beds. The beds extend below sea level and were apparently deposited on a deeply dissected surface, since Precambrian basement rocks occur up to about 150 feet above sea level just inland from Ann Bay.

Scattered outcrops of limestone occur up to at least 300 feet above sea level around the low hills east of Green Point and also in the Redpa area (Fig. 3; Nye, 1941; Gill and Banks, 1956; Gulline, 1959). The beds are at least 150 feet thick, and Quilty (in press) assigns them a Batesfordian age (Faunal Unit 9 of Carter, 1958). It is noticeable that the outcrops fringe the mound of Marrawah Volcanics, and in the Green Point area the hills behind the limestone outcrops are capped with the volcanics. South of Redpa the limestones rest on steeply dipping Precambrian dolomite, and the base is about 130 feet above sea level (Nye, 1941). However, in the other areas the base of the limestones is not exposed, and their relationship to the Marrawah Volcanics is difficult to determine.

There are continuous outcrops of volcanics down the Marrawah Beach road from about 300 feet above sea level to below the level of the adjacent Precambrian basement, indicating that the limestones do not form a laterally continuous unit. Thus *either* the limestones are older and were deeply eroded prior to the eruption of the volcanics, *or* they are younger and were deposited in separated valleys cut through the volcanics. The limestone in a small quarry in this area contains many angular to sub-rounded fragments of weathered basalt, up to 8 inches or so long, some of which show tachylitic margins and large vesicles. Thin sections (133, 134, 135) of some of the fragments showed them to have textures identical to those shown by the Marrawah Volcanics.

Thus there is strong evidence that the Marrawah Volcanics are older than the Miocene limestones and were subject to considerable erosion prior to the deposition of the limestones. The distribution of the limestone outcrops suggests the sediments were deposited in deep valleys cut in the flanks of the mound of volcanics, as seems to be the case at Cape Grim.

Temma area

A small outcrop of Tertiary limestone occurs near Temma (Ward, 1911; Longman and Matthews, 1962). The limestone is about 250 feet above sea level and is less than 20 feet thick. It rests unconformably on "Younger" Precambrian rocks and is overlain by the Temma Basalt (Fig. 4). Banks (1957, 1962a) suggests the fossils from this limestone possibly indicate a Balcombian age, but no detailed examination of the fauna has been made, and the limestone may be equivalent to the Batesfordian limestone at Marrawah.

The majority of aboriginal stone implements found in the Temma area are composed of spongolite. This spongolite is of marine origin and probably of Tertiary age (P. G. Quilty, pers. comm.). Boulders of similar rock, probably derived from the Miocene limestone, have been observed between Possum Creek and No Mans Creek just west of the basalt outcrops (Prof. W. Jackson, University of Tasmania, pers. comm.). An outcrop of similar rock was observed near sea level a little north of Mt. Cameron West (Mr. E. Abblitt, pers. comm.) and was probably the source of the aboriginal spongolite implements found in that area.

Pebbles of Tertiary limestone occur along the beach between Ordnance Point and Greens Creek, south of Temma (Ward, 1911), suggesting that limestone outcrops occur below sea level in this area.

Mt. Cameron West Basalt

The Mt. Cameron West Basalt is that massive basalt, at least 500 feet thick, composing Mt. Cameron West and disconformably overlying Upper Longfordian limestone near sea level. The basalt has been described by Edwards (1940a, b), Thomas (1945), and Gill and Banks (1956). It extends below sea level to the west and appears to represent a single flow. The basalt shows well developed columnar jointing and has pipe amygdales near its contact with the limestone in some places. It shows flow structure where its base steps down

over a small ledge cut in the limestone beneath its southern flank, indicating flow down the valley from the east.

Petrology

The petrology of this basalt is markedly different from that of the other basalts examined, and it was classified as an analcite-olivine dolerite by Edwards (1940b).

Chilled basalt from within 5 feet of the contact, in thin sections (136, 137) showed olivine phenocrysts set in a fine grained groundmass of feldspar, pyroxene and iron ore. The olivine crystals range up to 2 mm across, are mostly strongly corroded, and have a composition of about Fo_{80-85} as suggested by the negative optical signs and 2V's of 80°-85°. The crystals are usually altered along margins and cracks with dense dustings of fine secondary magnetite, and in places show more extensive alteration to chlorite. Many of the olivines contain small inclusions of anhedral pyroxene and squarish grains of iron ore similar to those in the matrix, indicating that crystallization of these constituents commenced during olivine growth. Feldspar forms 50-60% of the rock as numerous laths and intersertal plates. Pyroxene occurs as small intergranular grains and prisms less than 0.1 mm long, with rare larger grains. It is a faintly coloured augite, weakly pleochroic from pale green to pink, and in places forms small segregations. Iron ore is disseminated through the groundmass as irregular to squarish grains averaging less than 0.05 mm. A little colourless glass is present, and contains slender needles and prisms of apatite. It is slightly analcitized in places, and includes patches of indeterminate greenish chloritized (?) and carbonatized matrix. A few amygdales are present, with fillings of carbonate, analcite, and other zeolites.

About 100 feet above the base, in thin section 138, the basalt is a much coarser rock. Olivine is abundant, forming 15-20% of the rock as grains and phenocrysts up to 3 mm across, with a tendency to be glomeroporphyritic. It shows 2 V's close to 90° and is altered to serpentine along crystal edges and cracks. Pyroxene has crystallised as large plates, up to 3 mm in size, ophitically intergrown with the feldspar and olivine and poikilitically enclosing smaller crystals of these minerals. The pyroxene is a titan-augite, showing conspicuous pleochroism and zoning, generally with paler coloured cores. The pleochroic scheme is X = straw yellow, Y, Z = violet. The feldspar forms laths and anhedral plates up to about 1.5 mm long. The laths have a composition of about Ab_{35} and show Carlsbad, albite and pericline twinning. Iron ore is present as irregular to skeletal crystals up to 1 mm long, in places intergrown with and moulding feldspars. Apatite is present as coarse prisms up to 1 mm long and as slender needles in the mesostasis. Analcite, greenish chloritized (?) and carbonatized material, and a little radiating zeolite, form the mesostasis.

Basalt samples from various heights above 150 feet to the top of Mt. Cameron West in thin sections (139, 140, 141, 157) are generally similar to that just described but differ in the nature of the pyroxene. In the higher samples this mineral occurs as much smaller prismatic crystals, rarely greater than 0.5 mm long, and is intergranular rather than forming large, ophitically intergrown plates. The body colour is paler, being mainly yellowish-brown, with any marked pleochroism being confined to the crystal edges. The prisms may form rare but conspicuous radiated segregations. Small biotite flakes are generally present, mostly formed around the iron ore, and the olivines show partial alteration to serpentine (?). Thus the Mt. Cameron West basalt represents an undersaturated alkali basalt magma, related to the teschenites and basanites.

A small xenolith within the basalt was observed in thin section 138 (Plate 4, Fig. 3). The xenolith is a strongly corroded fragment 3 mm x 2 mm, mantled along most of its margin by a zone up to 0.9 mm wide composed of a very fine grained mosaic of plagioclase (?) with some granular iron ore. In one place this mosaic shows a tendency to a sheaf-like alignment normal to a concave surface of the fragment, with a row of thin plates of iron ore followed by a dusting of fine magnetite near the contact. The fragment has a dense rim of small grains of iron ore and greenish cubic and octahedral spinels up to 0.05 mm in size. The fragment consists of anhedral plagioclase (probably labradorite) as laths and plates, 0.3 to 0.5 mm long, poikilitically enclosing numerous prisms of colourless orthopyroxene (?) up to 0.1 mm long, prisms of sillimanite or mullite (?), and small greenish spinels. There are also patches of cloudy glassy material containing crystallites. Part of the xenolith shows strong development of the sillimanite (?) as elongate prisms up to 0.4 mm long growing inward from the margin amidst a finer felted mass of the mineral. The xenolith appears to represent a thermally metamarphosed basaltic (?) inclusion, and the outer zone possibly represents a fusion rim of feldspathic glass, now devitrified.

Origin and age

The Mt. Cameron West Basalt is probably a single flow which filled a deep valley cut in the underlying sediments and extended below present sea level. The only indication of flow direction suggests flow from the east. The valley was presumably cut during a period of lowered sea level and represents a considerable period of erosion, while the massive nature of the basalt and the lack of pillow structure, brecciation, &c., indicate that the flow was erupted subaerially. The most likely times at which such conditions were present, considering the fact that marine transgression affected the area during Longfordian and Batesfordian times, and from the evidence of sea level fluctuations in other Bass Strait areas (Jennings, 1957; Gill, 1962; Bowler, 1963; Bock and Glenie, 1965), were during the Upper Miocene-Pliocene and during the Pleistocene. Considerable erosion of the confining valley walls is indicated by the present prominent exposure of the basalt ridge, suggesting that a Pliocene age is more probable.

Basalt dyke

An isolated basalt dyke, 1 foot wide and 10 feet long, was observed in the Upper Longfordian sediments at about low tide level on the beach of Ann Bay, about 2 miles north of the Marrawah camping ground (Fig. 3). A thin section (142) from this dyke texturally resembles a slightly coarser variety of the chilled contact at Mt. Cameron West, and the

pyroxene is a strongly pleochroic titan-augite. The phenocrystic olivine has been completely altered to carbonate, but contains small inclusions of pyroxene and iron ore, as in the Mt. Cameron West Basalt. Numerous small oval vesicles are present, generally lined with botryoidally layered carbonate and limonite (?) and filled with calcite and/or analcite and other zeolites.

Buchites

Just north of Mt. Cameron West several boulders of conglomeratic rock were found amongst the basalt pebbles on the shore. The rock consists of white quartzite fragments, up to several inches across, set in a speckled bluish-grey matrix. Some of the quartzite fragments have indefinite borders while others have sharp borders with a thin dense marginal zone. Thin sections (143, 144) showed an unusual rock consisting of strongly corroded and fused quartzite fragments set in a glassy groundmass containing numerous elongate crystals of sanidine and pyroxene (Plate IV, Fig. 4). Most of the quartzite fragments show strongly corroded quartz grains in an almost colourless to brownish glass that may form up to 70% of the fragment. The quartz grains are fringed with needles of tridymite (?) which have grown both inwards and outwards from the margins, and the intervening glass is laced with numerous long, thin crystals of tridymite and/or sillimanite or mullite up to 0.5 mm long but mostly much less. The borders of the fused quartzite fragments are generally darker and grade into the glassy matrix.

This matrix is composed of two types of glass. One is pale coloured to almost colourless, with some cloudy patches due to granulation with minute globules of iron ore (?). The other is brownish and forms globular to elongated patches, up to 2 mm across, within the first type. The edges of these patches are irregular and generally dark with concentrations of granular iron ore, and the glass shows a tendency to devitrify and become anisotropic. The lighter coloured glass is the more abundant, although in parts the two are present in approximately equal proportions.

Numerous elongate crystals of sanidine and pyroxene have grown in the glassy groundmass. The sanidine (25-30% of the groundmass) occurs as skeletal crystals, with euhedral to subhedral outlines, forming laths, with squarish to rectangular cross-sections, up to 2 mm but mostly less than 1 mm in length. In a few places radiating and sheaf-like groups of the crystals have formed, possibly representing growth around a nucleus. The sanidine shows Carlsbad twinning and tends to be associated with the brownish glass, which fills the hollow interiors of the crystals. Rare squarish tablets of feldspar, up to 0.5 mm across, with strongly vermiculated cores and thin sanidine outgrowths, are also present. The pyroxene (10-15% of the groundmass) occurs as colourless, euhedral to subhedral prisms up to about 1 mm long. It is mostly orthopyroxene, probably enstatite, but some clinopyroxene, probably diopside, also occurs. The pyroxene is mostly associated with the lighter coloured glass. There is a colourless fringe around many of the crystals due to the absence of iron ore globules, the iron presumably having been incorporated into the pyroxene.

Other minerals are developed to a lesser extent in the groundmass. One area, 5 mm x 2 mm, lacks the usual crystals and shows considerable development of sillimanite or mullite (?), associated with squarish prisms and hexagonal plates of cordierite less than 0.1 mm long, thin rods of iron ore, and small globules of yellowish green opal. Cordierite also occurs within small blotches of brownish glass around the margins of the more impure quartzite fragments. Rare patches composed almost entirely of small, stumpy plagioclase laths, probably labradorite, also occur, as well as isolated corroded quartz crystals and small quartzite fragments.

The mineralogy of this rock suggests it is a buchite formed by strong thermal metamorphism of a conglomerate containing numerous quartzite or sandstone pebbles and some argillite fragments. Some of the quartz grains show undulose extinction typical of the Precambrian quartzites, suggesting the quartzite fragments were derived from local Precambrian quartzites like those at Green Point. Buchites have been previously described in Tasmania from the Apsley area, where Triassic sandstones have been baked adjacent to a Tertiary basalt neck (Spry and Solomon, 1964). The fused textures developed in the sandstone at Apsley in many respects resemble those in the quartzite fragments just described, although many of the latter lack the development of cordierite, possibly due to the absence of a clay cement.

The sanidine-pyroxene glassy groundmass of the rock presumably represents the metamorphosed matrix of the conglomerate, but its original composition is difficult to determine precisely. The presence of patches of one glass within another suggests either development of two immiscible liquids on fusion (Spry and Solomon, 1964, p. 528), or areas undergoing devitrification within a glass. The boulders have either washed up from around a basalt neck near the shores of Mt. Cameron West, or were derived from inclusions weathered out of the basalt flow.

Little Trefoil Basalts

The Little Trefoil Basalts include those massive basalts, at least 50 feet thick, exposed between Woolnorth Point and Cape Grim, around the eastern shore of Trefoil Island, and on Little Trefoil Island. The basalts disconformably overlie the Woolnorth Tuff, Slaughter Bluff Volcanic Breccia, Trefoil Island Volcanic Breccia, and the Cape Grim Beds.

The southernmost exposure is at Cape Grim, where a small outcrop of massive basalt, showing spheroidal weathering, overlies the Cape Grim Beds about 150-200 feet above sea level. Just north of Cape Grim massive basalt outcrops on the foreshore as vertical to sub-vertical dyke-like bodies (Plate III, Figs. 5, 6). These trend easterly to northeasterly and cut the Woolnorth Tuff and Slaughter Bluff Volcanic Breccia. They are up to 10 feet wide and 30 feet high, and form curved, bifurcating bodies in plan. They strongly resemble dykes but could possibly be interpreted as fillings of erosional channels in the sub-basalt surface. Ropy flow structure was observed on the inner surface of the large dyke shown in Plate III, Fig. 6.

A flow of massive basalt outcrops almost continuously along the shore from just north of the

dyke-like bodies to the south-west part of Woolnorth Point (Fig. 2). The thickness exposed is mostly less than 15 feet. The basalt extends below present sea level, although the Woolnorth Tuff is exposed through erosion windows in the floor of the flow in places, and sub-basalt cliffs in the tuff are also exposed. Much of the basalt shows well developed cooling columns, the majority being vertical and 1-2 feet across, with some up to 5 feet across. Where the edge of the basalt cuts across a small fault in the Woolnorth Tuff, three-quarters of a mile north of Cape Grim, there is no displacement of the basalt. The main basalt outcrop ends abruptly to the north with a straight north-westerly trending contact with the Precambrian. This contact corresponds to a fault downthrowing the Woolnorth Tuff against the Precambrian, which apparently formed a small scarp against which the basalt lapped. Basalt shingles form beach ridges on the eastern side of Woolnorth Point (Edwards, 1941a). The basalt is a saturated black glass type (Edwards, 1950) and the shingles were most probably derived from the Little Trefoil Basalts.

Massive basalt, with well developed cooling columns, is conspicuous along the eastern shore of Trefoil Island, where it overlies old platforms cut in the Woolnorth Tuff and the Trefoil Island Volcanic Breccia, and abuts against old cliffs in the breccia with a very irregular contact. The basalt is at least 50 feet thick and extends below sea level.

Petrology

Thin sections of samples from all the occurrences of massive basalt described above show saturated black glass olivine-basalt types of Spry (1962), with some variations in texture.

A sample from the outcrop above the Cape Grim Beds in thin section (145) is a somewhat weathered basalt but otherwise closely resembles the basalts of the Slaughter Bluff Volcanic Breccia. Like them it contains a little phenocrystic pyroxene that may form ring-like clusters around olivine phenocrysts. However, the glassy groundmass is crystallized to a greater extent, and the rock texturally approaches the Jordan Type of McDougall (1959).

Basalt from the dykes and the flow north of Cape Grim (thin sections 146, 147, 148, 149) is similar, but the groundmass is almost completely crystallized. Olivine forms about 8-12% of the rock in typical grains and corroded phenocrysts, up to 2.2 mm across, altered along cracks and margins to dark brownish nontronite (?). Plagioclase (40-45%) occurs as laths and anhedral plates mostly less than 1 mm long, and is labradorite with composition Ab_{40-35}. The groundmass pyroxene is a colourless to faintly pinkish very weakly pleochroic augite occurring in grains and prisms rarely longer than 0.5 mm. The pyroxene tends to be intergranular to subophitic toward the feldspar laths, and in cases is poikilitically enclosed by the intersertal feldspar. Iron ore (5-10%) has crystallized with a tendency to form elongated laths up to 1 mm long. Small irregular to rounded amygdales in the groundmass are filled with carbonate, nontronite (?) or opal.

The basalt from the dykes differs from that of the flow in having 3-5% phenocrystic pyroxene similar to that in the outcrop above the Cape Grim Beds. The phenocrysts which are up to 2.5 mm across, consist of a number of pyroxene plates welded together, and are pale fawn augite, generally riddled with inclusions of olivine, iron ore, glass, and other materials. In places the pyroxenes are intergrown with olivine crystals. The basalts resemble the Jordan Type of McDougall (1959).

Thin sections (150, 151) of the massive basalts from the eastern part of Trefoil Island are less crystallized types than those above. They have a hyloophitic textured black glass groundmass, and are related to the Ouse and Bridgewater Types (Edwards, 1950; McDougall, 1959). No phenocrystic pyroxene was observed, and in thin section this basalt closely resembles the Slaughter Bluff Volcanic Breccia horizon below the Valley Bay Conglomerate. Section 152 differs slightly in that pyroxene has crystallized from the glassy mesostasis as sheaves of thin, elongate prisms intergrown with the feldspar.

A chemical analysis of a basalt sample (section 147) is given in Table 2, and is again typical of the saturated black glass basalts of Tasmania (Spry, 1962), being slightly poorer in silica and richer in magnesia than the sample from the Slaughter Bluff Volcanic Breccia (q.v.)

Origin

Petrologically, all the basalt types represented in the Little Trefoil Basalts can be derived from variations in cooling conditions in a single flow, but it is also possible that each occurrence represents a different eruption. The massive nature, well developed cooling columns, and the lack of pillow structure or brecciation indicate that the eruptions were subaerial. If a single flow is represented, then the difference in level between the basalt above the Cape Grim Beds and that along the shore to the north can be explained by eruptions from the vent of the old fissure volcano off the Doughboys. The lava in this case flowed down the north-east flank, over the shelf formed by the Cape Grim Beds, and on through the low area between Woolnorth Point and Trefoil Island. Alternatively, much of the lava may have been derived from the "dykes" just north of Cape Grim.

The Trefoil Island basalts appear more glassy than the others, and while this may have been due to more rapid cooling on the western margin of the same flow, it could mean that these basalts belong to a separate flow, possibly derived from the old volcanic centre east of Trefoil Island.

Age

The Little Trefoil Basalts are younger than the Upper Longfordian Cape Grim Beds, where they overlie. The eruptions were subaerial, and the basalts flowed down valleys cut below present sea level. Periods of low sea level occurred in the Upper Miocene-Pliocene and in the Pleistocene (Bowler, 1964; Bock and Glenie, 1965, Jennings, 1959). The degree of dissection of the basalt suggests the older age is the more likely.

Temma Basalt

Massive basalt, up to 100 feet thick, outcrops in the Temma area, and its distribution is shown in Fig. 4. Most of the outcrops probably represent

remnants of a single flow. The basalt unconformably overlies "Younger" Precambrian rocks, and at one place overlies and bakes Miocene limestone (Ward, 1911; Hughes, 1957; Longman and Matthews, 1962; Banks, 1962a). The base of the basalt descends westwards from over 300 feet to about 220 feet above sea level. The location of the eruptive centre is not known.

A thin section (153) of a sample from the outcrop on the Balfour track just south of Possum Creek showed a porphyritic olivine black glass labradorite basalt, with a partly crystallized hyaloophitic glassy groundmass containing elongate prisms of augite. The section mineralogically and texturally closely resembles section 152 from the Little Trefoil Basalts, and shows affinity with the Bridgewater and Jordan Types (Edwards, 1950; McDougall, 1959).

The Temma Basalt is younger than the underlying Middle (?) Miocene limestone and appears to represent subaerial eruption following considerable and in places complete erosion of the limestone. This erosion probably took place during the Upper Miocene-Pliocene regression in western Bass Strait (Bock and Glenie, 1965; Bowler, 1964), and the degree of dissection of the basalt suggests a Pliocene rather than a Quaternary age. Thus the Temma Basalt is probably similar in age to the Little Trefoil and Mt. Cameron West Basalts.

Ordnance Point area

Basalt shingles occur along the beach between Ordnance Point and Greens (Daisy) Creek, apparently derived from offshore outcrops (Ward, 1911). A thin section (154) of a pebble showed it to be a black glass type similar to that described from the Temma Basalt but with a more abundant glassy mesostasis, and is related to the Bridgewater Type (Edwards, 1950; McDougall, 1959).

Fragments of basalt conglomerate were also collected from this area. The conglomerates are generally fine grained but one specimen consisted of fragments of vesicular and dense basalt, up to several inches across, in a very abundant calcite matrix. The more common conglomerate consists of fragments of tachylitic basalt, mostly less than 1 inch across, in a matrix of smaller fragments and abundant calcite. A thin section (155) showed the rock to consist of a random mixture of angular to rounded black glass basalt fragments, mostly of the Ouse Type but also of the more crystallized Bridgewater and Jordan Types (Edwards, 1950; McDougall, 1959). In many of the fragments the black glass has been completely altered to yellow palagonite, but in others it is completely fresh. The fragments are set in a matrix of recrystallized calcite forming about 30-40% of the rock. In some respects the rock resembles the palagonitised tachylitic matrix found in the Trefoil Island and Slaughter Bluff Volcanic Breccias and in the Marrawah Volcanics, but differs in that the fragments show some rounding and are not all palagonitised.

Two possible origins are suggested for this conglomerate. Firstly, it may represent redeposited detritus derived from an off-shore basalt breccia similar to the pillow breccias at Trefoil Island, Cape Grim and Marrawah. The fragments of unpalagonitised basalt would be derived from the basalt blocks or pillows, and the palagonitised fragments from the brecciated matrix. Alternatively, the detritus may have been derived from a "littoral cone" formed where the Temma Basalt flowed into the sea and was chilled, fragmented and palagonitised. Such cones are described from Hawaii by Moore and Ault (1965). More crystallized patches of lava protected from contact with sea water would form the unpalagonitised and less chilled basalt.

PROPOSED ERUPTIVE HISTORY

Volcanism commenced in far north-western Tasmania probably in the Lower Tertiary, with explosive activity in the vicinity of Trefoil Island and possibly elsewhere. Vitric olivine-basalt tuffs from the eruptions accumulated to depths of over 30 feet in shallow marine (?) waters over an area of at least several square miles, forming the Woolnorth Tuff.

An erosion surface, with cliffs and platforms, was cut in this tuff following regression of the sea, possibly during Upper Palaeocene-Upper Eocene times. Further volcanism took place, this time with extrusions of saturated phenocrystic olivine basalt from a vent west of Flat Topped Bluff. The early flow or flows consisted mainly of entrail lava, this form possibly being the result of slow, restricted flow over the irregular erosion surface of the tuff, although contact with shallow water may have occurred in places. Whether the massive basalts which form the upper part of the Studland Bay Basalts were also erupted during this period is not certain, and they may represent much later effusions.

Marine transgression began, possibly in or shortly before Oligocene time, after these eruptions. Detritus derived from erosion of the basalt accumulated below sea level at the base of cliffs in the Valley Bay area, forming the Valley Bay Conglomerate. The pillow breccia underlying this conglomerate probably represents eruptions from the centre off Flat Topped Bluff into this encroaching sea.

General marine submergence had taken place when this fissure became strongly active again, probably in the Oligocene. A succession of saturated phenocrystic olivine basalt lavas were poured out as submarine flows, accompanied by brecciation and pillow development, to form the large cone of Slaughter Bluff Volcanic Breccia. Xenoliths of the older Studland Bay Basalts were apparently incorporated into the flows, as well as fragments of the underlying Woolnorth Tuff and Precambrian quartzites. Pyroxene had begun to crystallize in the magma chamber by this stage, and was carried up as phenocrysts with the olivine. Submarine centres or fissures east of Trefoil Island and east of Marrawah also probably became active about this time, forming the Trefoil Island Volcanic Breccia and the Marrawah Volcanics. Pyroxene phenocrysts are apparently absent from these two rocks, suggesting that pyroxene had not begun to crystallize in their magmas at the time of extrusion. The Marrawah Volcanics occur further inland and at a relatively higher level than the other volcanic cones suggesting that the Marrawah volcano may have been closer to the original shoreline. This could account for the presence of massive flows within the volcanics.

The submarine eruptions appear to have been followed by complete or partial marine regression, possibly in the Upper Oligocene, exposing the volcanic cones to erosion. This was followed by widespread marine transgression in the Lower Miocene, represented in this area by the Upper Longfordian and Batesfordian limestones deposited around the partly eroded volcanic cones in the Slaughter Bluff and Marrawah areas.

Regression of this high sea appears to have commenced before the end of the Miocene, followed by erosion and deep dissection of the newly deposited sediments, the old volcanic cones and the Woolnorth Tuff. Deep valleys were carved to below present sea level, probably by Lower Pliocene time. Renewed volcanism, probably in the Pliocene, filled these valleys with lava. A flow or flows of saturated phenocrystic olivine basalt, probably extruded from the Slaughter Bluff fissure and possibly also from the centre east of Trefoil Island, filled a broad valley between Trefoil Island and Woolnorth Point, forming the Little Trefoil Basalts. Crystallization of some of the groundmass constituents had progressed in the magma, below this centre, by this time, and pyroxene phenocrysts, riddled with inclusions of these constituents, were carried up with the olivine phenocrysts. A saturated phenocrystic olivine basalt flow was also extruded in the Temma area, forming the Temma Basalt, and this possibly flowed down into the sea to form a littoral cone off Ordnance Point.

A lava entirely different to those of all the other Tertiary eruptions in the area was extruded in the vicinity of Mt. Cameron West at about this time. Here a flow of undersaturated phenocrystic olivine alkali basalt filled a valley to a depth of at least 500 feet, forming the Mt. Cameron West Basalt. Rocks around, or incorporated into, the volcanic vent, were metamorphosed and fused to form buchites.

Volcanic activity in the area probably ceased prior to the beginning of the Quaternary, since which time the volcanic rocks and associated sediments have been subject to further erosion and dissection, and in places covered with dunes and other Quaternary deposits.

DISCUSSION

The far north-west of Tasmania is a Cainozoic volcanic province characterized by extrusions dominantly of saturated phenocrystic olivine black glass basalts, with localized extrusion of undersaturated phenocrystic olivine alkali basalt. The initial extrusion, which produced the Woolnorth Tuff, was explosive, but all subsequent activity appears to have been effusive. Although the lava type remained essentially uniform, two very different forms of basalt were produced, viz., massive, columnar basalt and basaltic pillow breccia. This is considered to have depended upon whether the eruptive centre was above or below sea level at the time of eruption. The pillow breccia basalts generally show a lesser degree of crystallization than the massive basalts, as would be expected in an aqueous environment. Some of the centres appear to have produced both forms at different times, indicating a fluctuating sea level. An attempt has been made to correlate these changes from subaerial to submarine volcanism with sea level fluctuations indicated by stratigraphic work in the Bass Strait area, and the results are promising. It would be of interest to check these results by other methods, such as palaeomagnetic or radioactive dating.

Further investigation of some of the basaltic islands in Bass Strait should provide additional information on the Cainozoic volcanism in relation to sea level fluctuations. Of interest in this regard is Black Pyramid, approximately 25 miles north-west of Cape Grim. One of the authors (F.L.S.) has examined colour photographs of the island taken on one of the rare landings (Green and MacDonald, 1963). These show massive basalts with well developed cooling columns forming the lower part of the island, overlain at about 100 feet above sea level by a prominent horizon of near-horizontal strata, followed by over 100 feet of apparently non-columnar, and possibly brecciated basalt (?). A thin section (156) of a basalt sample collected by R. H. Green from the lower columnar horizon showed it to be a porphyritic saturated olivine basalt similar to sections 147, 148, and 149 of the Little Trefoil Basalts.

The pillow basalts described show similarities in form to the Cambrian pillow lavas of Tasmania (Scott, 1951, 1952; Solomon, 1964), but are markedly different petrologically, the Cambrian lavas being invariably spilitic in nature. There are few previous records of Tertiary pillow basalts in Tasmania. Banks (1962b) briefly records the pillow form of the basalt at Cape Grim (Slaughter Bluff Volcanic Breccia). Banks (1955) and Anandalwar (1957) describe a horizon of pillow lava up to 50 feet thick from Macquarie Plains, in the Derwent Valley, and attribute it to possible extrusion into a small lake. Voisey (1949) describes a 215 foot section of "block lavas" and tachylitic breccias in the Liawenee Canal and around the shores of Great Lake in the Central Plateau. He remarked on the similarity of the block lava to pillow basalts but did not directly equate them with subaqueous extrusion. The present authors have re-examined these exposures and were struck with their similarity to the pillow breccias in the far north-west. The basalt type is likewise similar (Edwards, 1950), while palaeomagnetic dating of basalts in this area indicate an Upper Cainozoic age (Green and Irving, 1958). The authors consider this rock represents extrusion of basalt into a former, and presumably freshwater, lake, possibly formed by damming of the drainage by the initial eruptions. Judging from the distribution of the rock, as mapped by Voisey (1949), the lake was at least half the size of the present Great Lake.

Comparison can also be made of the abundant zeolites and associated amygdale minerals found in the "block" basalt at Great Lake (Sutherland, 1965) with those in the pillow breccias of the far north-west. The two mineral suites are somewhat similar, but differ mainly in the presence of soda-rich zeolites (natrolite and sodic chabazite) in the latter. Whether this difference can be attributed to extrusion into a freshwater environment at Great Lake as compared to a marine environment in the far north-west is not yet certain.

It is of interest to compare the Tasmanian Cainozoic pillow lavas and breccias with similar rocks in the Cainozoic volcanics of Victoria (Condon, 1951; Bowler, 1963). The "boulder tuff"

reported by Stach and McIvor (1937) from Lady Percy Julia Island also appears, from their description, to be a pillow breccia. From these comparisons it is apparent that in both Tasmania and Victoria pillow basalts were formed by subaqueous extrusions, into either marine or freshwater environments, at various times in the Cainozoic, and that saturated to near saturated olivine basalts were mostly involved.

The present study provides further information on the relationship between basalt magma type and the Cainozoic volcanic history of Tasmania. The preliminary survey of Edwards (1950) indicated that petrologically the Tasmanian basalts did not fall into an older series (characterized by undersaturated titan-augite basalts and of Lower Tertiary age) and a younger series (characterized by saturated black glass basalts and of Upper Pliocene to Quaternary age) as in Victoria. Edwards, however, based his conclusions partly on the fact that in the Launceston area undersaturated titan-augite basalts, similar to those of the older series of Victoria, disconformably overlie sediments he considered to be Miocene. Subsequent dating, however, has shown these sediments to be as old as Palaeocene-Eocene (Gill and Banks, 1956; Gill, 1962), and recent field investigation suggests the basalts may not be younger than early Miocene (Sutherland, 1966). Nevertheless, the results of the present study confirm Edward's initial conclusion, since the saturated black glass basalts of the far north-west are considered to range in age from Pliocene to pre-Miocene and to be possibly as old as Palaeocene-Eocene. The undersaturated titan-augite Mt. Cameron West Basalt, on the other hand, is probably as young as Upper Miocene-Pliocene. Thus the Cainozoic magmatic history of Tasmania, in the far north-west at least, appears to be significantly different to that of Victoria.

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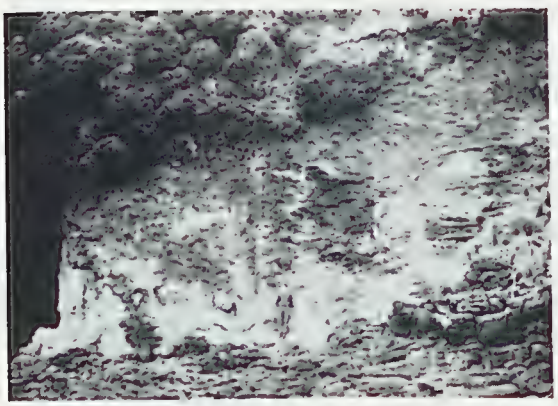

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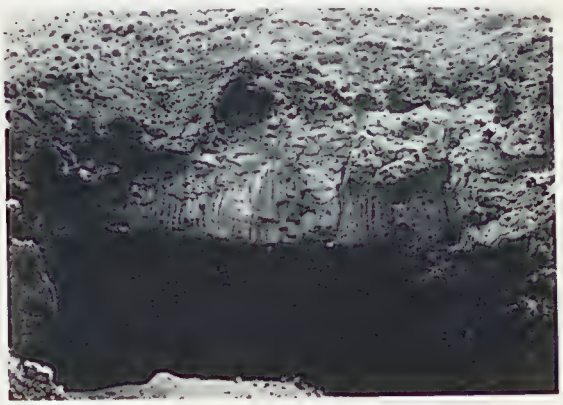

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Plate I.

Fig. 1.—Woolnorth Tuff. Note prominent horizontal bedding, folding adjacent to small fault, development of cliffs and platforms. Outcrop in type area, ¾ mile north of Cape Grim, looking north.

Fig. 2.—Woolnorth Tuff. Note climbing ripple lamination, thin, lighter coloured bands. Locality as for Fig. 1, looking north.

Fig. 3.—Exhumed cliff of Woolnorth Tuff exposed under Studland Bay Basalts, just south of Valley Bay, looking east. Note entrail lava above cliff, columnar basalt at cliff base, horizontal and contorted bedding and clastic dykes in tuff.

Fig. 4.—Studland Bay Basalts. Lens of columnar basalt within entrail basalt forms roof of sea cave, Locality approx. 50 feet south of Fig. 3.

Fig. 5.—Typical entrail lava of Studland Bay Basalts, near sea level just south of Valley Bay. Hammer rests on small outcrop of Woolnorth Tuff.

Fig. 6.—Trefoil Island Volcanic Breccia. Boulder showing small pillows with tachylitic margins and large, mineral-filled central vesicles, in typical calcareous tachylitic matrix.

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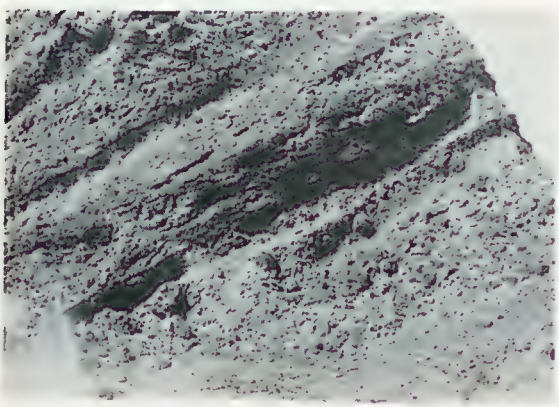

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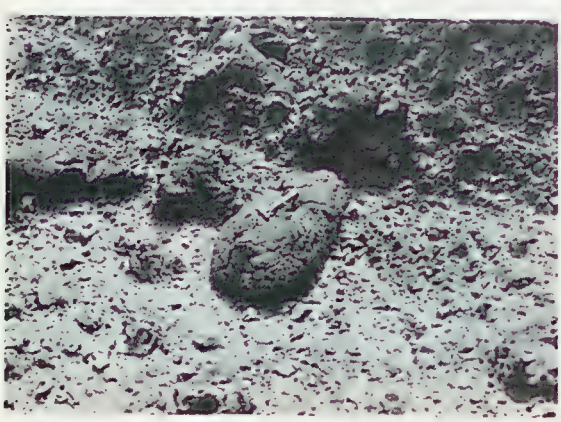

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PLATE II.

FIG. 1.—Valley Bay Conglomerate. Upper contact with small flow of pillowy lava in Slaughter Bluff Volcanic Brecia. Note large boulders of amygdaloidal basalt in abundant sandy matrix.

FIG. 2.—Valley Bay Conglomerate. Note large boulders, lateral variations in lithology. Looking east.

FIG. 3.—Slaughter Bluff Volcanic Breccia. Note crude inclined bedding, variations in proportions of pillows, fragments and matrix in different layers, lighter coloured zones at tops of beds. West side of Cape Grim.

FIG. 4.—Cape Grim Beds in channel in Slaughter Bluff Volcanic Breccia, east side of Cape Grim, looking north with Trefoil Island in the background. Note coarse "cross-bedding" in breccia.

FIG. 5.—Isolated pillow, with broken-off rear end, in Slaughter Bluff Volcanic Breccia, south of Cape Grim.

FIG. 6.—Typical view of Slaughter Bluff Volcanic Breccia. Note broken pillows and fragments with double and multiple cooling crusts. West side of Cape Grim.

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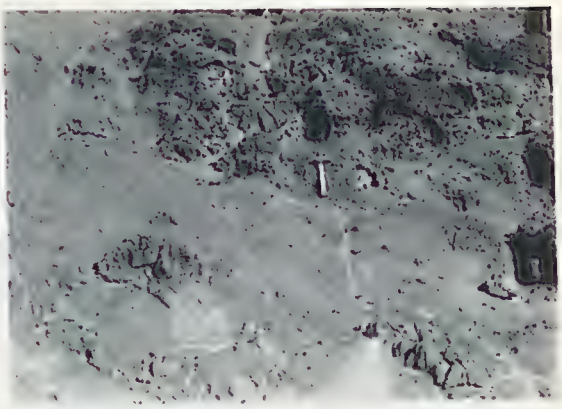

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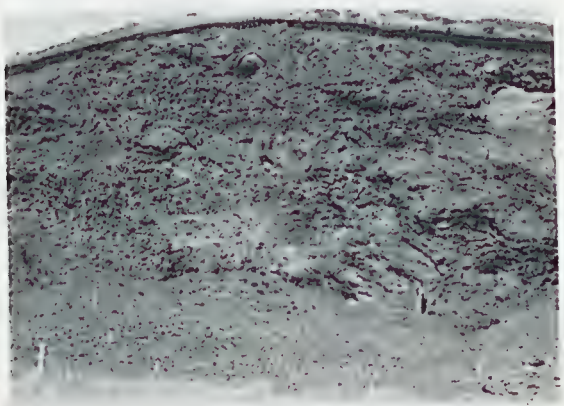

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Plate III.

Fig. 1.—Pillowy lava in Slaughter Bluff Volcanic Breccia. Note moulded form of pillows. South side of Cape Grim.

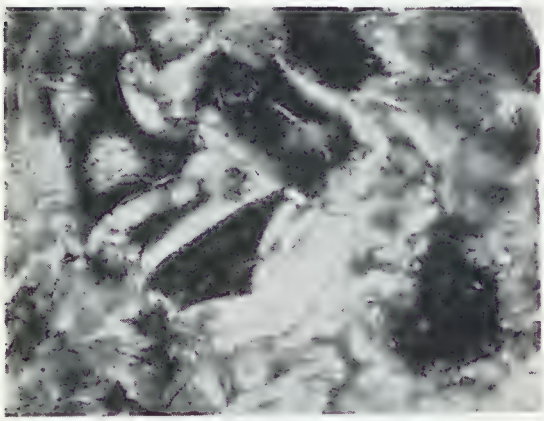
Fig. 2. Layer rich in matrix, Slaughter Bluff Volcanic Breccia. Note block of amygdaloidal basalt in left foreground. West side of Cape Grim.

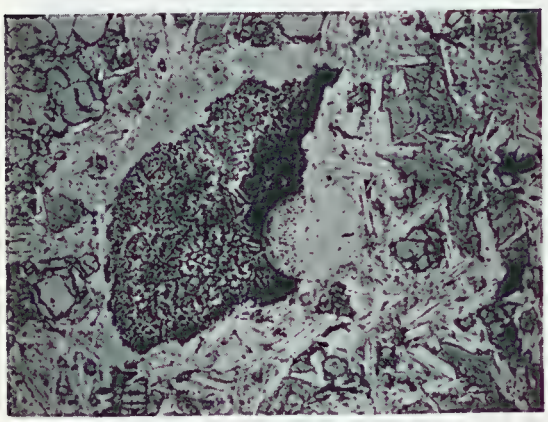
Fig. 3.—Marrawah Volcanics, quarry on Marrawah Beach road. Note variations in proportions of pillows, blocks and matrix.

Fig. 4.—Flow of massive basalt within pillow breccias, Marrawah Volcanics. Quarry near Bass Highway, 2 miles south-west of Redpa. Looking North.

Fig. 5.—Dyke-like body of Little Trefoil Basalt in Woolnorth Tuff. Note veneer of breccia on tuff to right. Shore platform just north of Cape Grim.

Fig. 6.—Dyke-like bodies of Little Trefoil Basalt. Note breccia overlying Woolnorth Tuff between the dykes. Shoreline cliff, just north of Cape Grim.





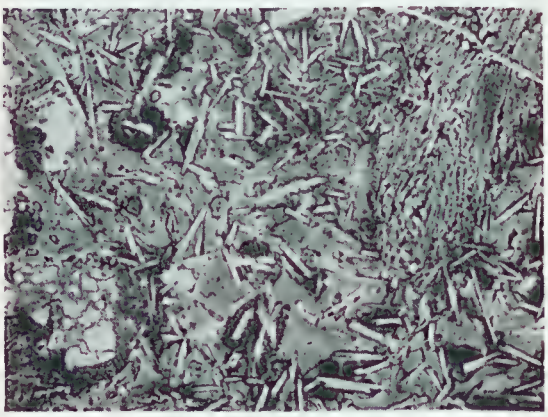


Plate IV.

Fig. 1.—Photomicrograph of Woolnorth Tuff. Note partial alteration of glass shards (dark); fringes of lussatite (?) on shards and olivine fragment (light); interstices filled with chalcedony. Crossed nichols.

Fig. 2.—Photomicrograph of matrix of Trefoil Island Volcanic Breccia. Fragments of vesicular palagonite (dark) cemented by calcite (white) with nests of gypsum (grey). Crossed nichols.

Fig. 3.—Photomicrograph of small xenolith in teschenitic Mt. Cameron West Basalt. Note reaction rim of plagioclase (?) and iron ore; dense border of iron ore and spinels; enstatite (?) and sillimanite (?) poikilitically enclosed by plagioclase. Ordinary light.

Fig. 4.—Photomicrograph of buchite from Mt. Cameron West. Note partially fused quartzite fragment (lower left); areas of darker and lighter coloured glass; sheaves and laths of sanidine; prisms of pyroxene. Ordinary light.

A LIST OF THE ARMOURED SCALE INSECTS (DIASPIDIDAE) AND THEIR HOSTS IN TASMANIA

By

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ABSTRACT

In this first list of the diaspidid scale insects occurring in Tasmania 40 species are recorded. The list is based exclusively on specimens held in the permanent collection of the Tasmanian Department of Agriculture. The host-plant list comprises 79 species from 32 families.

INTRODUCTION

No previous list of the armoured scale insects has ever been published for Tasmania. The list which is restricted to the specimens present in the collection of the Department of Agriculture, Hobart is divided into 3 sections. The first is a list of the scale species arranged in alphabetical order containing details of hosts and localities; the second is an alphabetical list of host plants together with details of the scale species found on them; and the third is an alphabetical list of the botanical families together with details of the host genera.

LIST OF SPECIES

Abgrallaspis cyanophylli (Signoret).

Host: *Cactus sp.*
Locality: Hobart (under glass).

Alioides sp.

Host: *Leptospermum lanigerum* Sm.
Locality: Nubeena.

Ancepaspis anomola (Green).

Hosts: *Acacia dealbata* Link, *Acacia mearnsii de* Wild, *Acacia melanoxylon* R. Br., *Eucalyptus amygdalina* Lab.

Localities: Bushy Park, Hayes, Huonville.

Ancepaspis sp.

Host: *Casuarina stricta* Ait.
Locality: Cremorne Beach.

Aspidiotus hederae (Vallot).

Hosts: *Acacia dealbata* Link, *Acacia mearnsii* de Wild, *Acacia melanoxylon* R. Br., *Acacia myrtifolia* Willd., *Aesculus hippocastanum* L., *Asparagus plumosus* Baker, *Boronia sp., Bouvardia sp., Cassia sp., Casuarina sp., Ceanothus sp., Cymbidium sp., Dodonaea viscosa Jacq., Erica sp., Exocarpos cupressiformis* Lab., *Howia sp., Kentia sp., Lauris noblis* L., *Leptospermum scoparium* Forst., *Macadamia tetraphyla* F. Muell., *Olea europea* L., *Phoenix sp., Psoralea pinnata* L., *Pyrus malus* L., *Ribes nigrum* L., *Sarothamnus scoparius* (L.), *Telopea truncata* R. Br., *Tulipa sp.*

Localities: Adventure Bay and Barnes Bay (Bruny Is.), Devonport, Hayes, Hobart, Lalla, New Norfolk.

Aulacaspis rosae (Bouché).

Hosts: *Crataegus sp., Pyrus malus* L., *Rosa spp.*

Localities: Hayes, Hobart, Margate.

Carulaspis juniperi (Bouché).

Hosts: *Cupressus sp., Cupressus macrocarpa* Hartw.

Localities: Grove, Legana.

Chrysomphalus trifasciculatus Brimblecombe.

Hosts: *Eucalyptus rubida* Deane & Maiden, *Eucalyptus sp.*

Locality: Hobart.

Clavaspis subfervens Green.

Host: *Acacia dealbata* Link.
Locality: Hayes.

Coccomytilus sp. (a).

Hosts: *Acacia dealbata* Link, *Acacia mearnsii* de Wild, *Acacia melanoxylon* R. Br.

Locality: Hayes.

Coccomytilus sp. (b).

Hosts: *Casuarina stricta* Ait., *Casuarina littoralis* Salisb.

Localities: Cremorne Beach, Howrah Beach, Lindisfarne, Margate.

Diaspis boisduvalii Signoret.

Host: *Cymbidium sp.*
Locality: Hobart.

Eucornuaspis machili (Maskell).

Hosts: *Cymbidium spp.*
Localities: Devonport, Hobart.

Fiorinia lidgetti ? Green.

Hosts: *Acacia dealbata* Link, *Acacia mearnsii* de Wild, *Acacia pycantha* Benth.
Locality: Hobart.

Fiorinia sp. near *acaciae* Maskell.

Hosts: *Acacia botrycephala* Desf., *Acacia mearnsii* de Wild, *Cassia sp.*
Localities: Bellerive, Cradoc.

Hemiberlesia rapax (Comst.).

Hosts: *Acacia mearnsii* de Wild, *Acacia sp., Callitris oblonga* Rich., *Ceanothus sp., Dianella tasmanica* Hook, *Ilex aquifolium* L., *Lauris nobilis* L., *Ligustrum vulgare* L., *Melaleuca squarrosa* Sm., *Myoporum serratum* R. Br., *Pyrus communis* L., *Pyrus malus* L., *Rhododendron sp.*

Localities: Cambridge, Cradoc, Cremorne Beach, Cooee, Hillwood, Hobart, Launceston, Middleton, New Norfolk, Rowella, South Arm, Taroona.

**Lepidosaphes grandilobus* (Maskell).
Host: *Banksia marginata* Cav.
Locality: Lindisfarne.

Lepidosaphes ulmi (L.).

Hosts: *Pyrus communis* L., *Pyrus malus* L.
Localities: Burnie, Launceston, Lilydale.

Lindingaspis rossi (Maskell).

Hosts: *Arbutus unedo* L., *Camellia japonica* L., *Cotoneaster sp.*, *Evonymus sp.*, *Hedera helix* L., *Nerium oleander* L.
Localities: Hobart, Launceston, Legana.

Monaonidiella sp.

Host: *Pittosporum bicolor* Hook.
Locality: Mt. Wellington.

Mytilaspis (*Lepidosaphes*) *multipora* (Leonardi).

Host: *Acacia melanoxylon* R. Br.
Locality: Margate.

Mytilaspis sp. near *eucalypti* Froggatt.

Hosts: *Acacia mearnsii* de Wild, *Acacia verticillata* Willd., *Banksia marginata* Cav., *Callitris tasmanica* Baker & Smith, *Eucalyptus amygdalina* Lab., *Exocarpos cupressiformis* Lab.
Localities: Cradoc, Hayes, Huonville, Lindisfarne, Orford.

Mytilaspis sp.

Host: *Diplarrena moraea* Lab.
Locality: Lindisfarne.

Neomorgania eucalypti (Maskell).

Hosts: *Acacia mearnsii* de Wild, *Acacia melanoxylon* R. Br.
Localities: Hayes, Hobart.

Parlatoria banksiae (Maskell).

Host: *Banksia marginata* Cav.
Localities: Carlton Beach, Lindisfarne.

Parlatoria pittospori Maskell.

Hosts: *Amperea xiphoclada* Spreng., *Callitris tasmanica* Baker & Smith, *Davesia ulicina* Sm., *Exocarpos stricta* R. Br.
Localities: Cradoc, Lindisfarne, Orford.

Parlatoria sp.

Host: *Exocarpos cupressiformis* Lab.
Locality: Hayes.

Phenacaspis australis Laing.

Hosts: *Eugenia sp.*, *Phoenix sp.*
Locality: Hobart.

Phenacaspis xerotidis (Maskell).

Host: *Lomandra longifolia* Lab.
Localities: Lindisfarne, Ouse.

Phenacaspis sp. near *chinensis* (Ckll.).

Hosts: *Acacia verticillata* Willd., *Anopterus glandulosus* Lab.
Localities: Hobart, Howden.

Phenacaspis sp. (a).

Host: *Melaleuca ericifolia* Sm.
Locality: Gravelly Beach

Phenacaspis sp. (b).

Host: *Epacris impressa* Lab.
Locality: Lindisfarne.

Phenacaspis sp. (c).

Host: *Casuarina littoralis* Salisb.
Locality: Lindisfarne.

Pinnaspis aspidistrae (Signoret).

Host: *Blechnum nudum* (Labill) Mettenius ex Luenssen.
Locality: Hobart (under glass).

Poliaspis exocarpi Maskell.

Hosts: *Davesia ulicina* Sm., *Exocarpos cupressiformis* Lab., *Exocarpos stricta* R. Br., *Pultenaea juniperina* Lab.
Localities: Cradoc, Hayes, Longley.

Poliaspis syringae Laing.

Host: *Bedfordia salicina* DC.
Locality: Mt. Wellington.

Poliaspis sp.

Hosts: *Amperea xiphoclada* Spreng., *Astroloma humifusum* R. Br., *Epacris impressa* Lab.
Locality: Lindisfarne.

Quadraspidiotus ostreaeformis (Curt.).

Hosts: *Acacia dealbata* Link, *Crataegus sp.*, *Prunus domestica* L., *Prunus serrulata* Lindl., *Pyrus communis* L., *Pyrus malus* L.
Localities: Glen Huon, Hayes, Huonville, Salmon Ponds, Sandford.

Quadraspidiotus perniciosus (Comst.).

Hosts: *Prunus serrulata* Lindl., *Pyrus communis* L., *Pyrus malus* L.
Locality: Launceston.

Quadraspidiotus pyri (Licht.).

Hosts: *Prunus avium* L., *Prunus domestica* L., *Prunus persica* L., *Prunus triloba* Lindl., *Pyrus communus* L., *Pyrus malus* L.
Localities: Birch's Bay, Claremont, Hayes, Hobart, Kingston, Margate, New Norfolk, Nubeena, Rowella, Sandfly, Sandford, Snug, Spreyton, Wattle Grove, Woodbridge.

HOST INDEX

Acacia botrycephala Desf.

Fiorinia sp. near *acaciae* Maskell.

Acacia dealbata Link.

Ancepaspis anomala (Green), *Aspidiotus hederae* (Vallot), *Clavaspis subfervens* Green, *Coccomytilus sp.* (a), *Fiorinia lidgetti* ? Green, *Quadraspidiotus ostreaeformis* (Curt.).

Acacia mearnsii de Wild.

Ancepaspis anomala (Green), *Aspidiotus hederae* (Vallot), *Coccomytilus sp.* (a), *Fiorinia lidgetti* ? Green, *Fiorinia sp.* near *acaciae* Mask., *Hemiberlesia rapax* (Comst.), *Mytilaspis sp.* near *eucalypti* Froggatt, *Neomorgania eucalypti* (Mask.).

* This species should not be retained in *Lepidosaphes* and is assigned to it here pending generic placement elsewhere.

Acacia melanoxylon R. Br.
Ancepaspis anomala (Green), *Aspidiotus hederae* (Vallot), *Coccomytilus sp.* (a), *Mytilaspis multipora* (Leon.), *Neomorgania eucalypti* (Mask.).

Acacia myrtifolia Sm.
Aspidiotus hederae (Vallot).

Acacia pycantha Benth.
Fiorinia lidgetti? Green.

Acacia sp.
Hemiberlesia rapax (Comst.).

Acacia verticillata Willd.
Mytilaspis sp. near *eucalypti Froggatt, Phenacaspis sp.* near *chinensis* (Ckll.).

Aesculus hippocastanum L.
Aspidiotus hederae (Vallot).

Amperea xiphoclada Spreng.
Parlatoria pittospori Mask., *Poliaspis* sp.

Anopterus glandulosus Lab.
Phenacaspis sp. near *chinensis* (Ckll.).

Arbutus unedo L.
Lindingaspis rossi (Mask.).

Asparagus plumosus Baker.
Aspidiotus hederae (Vallot).

Astroloma humifusum R. Br.
Poliaspis sp.

Atherosperma moschatum Lab.
Phenacaspis sp. near *chinensis* (Ckll.).

Banksia marginata Cav.
Lepidosaphes grandilobus (Mask.), *Mytilaspis sp.*, near *eucalypti* Froggatt, *Parlatoria banksiae* (Mask.).

Bedfordia salicina DC.
Poliaspis syringae Laing.

Blechnum nudum (Labill) Mettenius ex Luenssen.
Pinnaspis aspidistrae (Signoret).

Boronia sp.
Aspidiotus hederae (Vallot).

Bouvardia sp.
Aspidiotus hederae (Vallot).

Cactus sp.
Abgrallaspis cyanophylli (Signoret).

Callitris tasmanica Baker & Smith.
Mytilaspis sp. near *eucalypti* Froggatt, *Parlatoria pittospori* Mask.

Callitris oblonga Rich.
Hemiberlesia rapax (Comst.).

Camellia japonica L.
Lindingaspis rossi (Mask.).

Cassia sp.
Aspidiotus hederae (Vallot), *Fiorinia* sp. near *acaciae* Mask.

Casuarina stricta Ait.
Ancepaspis sp., Coccomytilus sp. (b).

Casuarina sp.
Aspidiotus hederae (Vallot).

Casuarina littoralis Salisb.
Coccomytilus sp. (b), *Phenacaspis sp.* (c).

Ceanothus sp.
Aspidiotus hederae (Vallot), *Hemiberlesia rapax* (Comst.).

Cotoneaster sp.
Lindingaspis rossi (Mask.).

Crataegus sp.
Aulacaspis rosae (Bouché), *Quadraspidiotus ostreaeformis* (Curt.).

Cupressus sp.
Carulaspis juniperi (Bouché).

Cupressus macrocarpa Hartw.
Carulaspis juniperi (Bouché).

Cymbidium spp.
Aspidiotus hederae (Vallot), *Diaspis boisduvalli* Signoret, *Eucornuaspis machili* (Mask.).

Davesia ulicina Sm.
Parlatoria pittospori Mask., *Poliaspis exocarpi* Mask.

Dianella tasmanica Hook.
Hemiberlesia rapax (Comst.).

Diplarrena moraea Lab.
Mytilaspis sp.

Dodonaea viscosa Jacq.
Aspidiotus hederae (Vallot).

Epacris impressa Lab.
Phenacaspis sp. (b), *Poliaspis sp.*

Erica sp.
Aspidiotus hederae (Vallot).

Eucalyptus amygdalina Lab.
Ancepaspis anomala (Green), *Mytilaspis sp.* near *eucalypti* Froggatt.

Eucalyptus rubida Deane and Maiden.
Chrysomphalus trifasciculatus Brimblecombe.

Eucalyptus sp.
Chrysomphalus trifasciculatus Brimblecombe.

Eugenia sp.
Phenacaspis australis Laing.

Evonymus sp.
Lindingaspis rossi (Mask.).

Exocarpos cupressiformis Lab.
Aspidiotus hederae (Vallot), *Mytilaspis sp.* near *eucalypti* Froggatt, *Parlatoria sp., Poliaspis exocarpi* Mask.

Exocarpos stricta R. Br.
Parlatoria pittospori Mask., *Poliaspis exocarpi* Mask.

Hedera helix L.
Lindingaspis rossi (Mask.).

Howia sp.
Aspidiotus hederae (Vallot).

Ilex aquifolium L.
Hemiberlesia rapax (Comst.).
Kentia sp.
Aspidiotus hederae (Vallot).
Lauris nobilis L.
Aspidiotus hederae (Vallot), *Hemiberlesia rapax* (Comst.).
Leptospermum lanigerum Sm.
Alioides sp.
Leptospermum scoparium Forst.
Aspidiotus hederae (Vallot).
Ligustrum vulgare L.
Hemiberlesia rapax (Comst.).
Lomandra longifolia Lab.
Phenacaspis xerotidis (Mask.).
Macadamia tetraphylla F. Muell.
Aspidiotus hederae (Vallot).
Melaleuca ericifolia Sm.
Phenacaspis sp. (a).
Melaleuca squarrosa Sm.
Hemiberlesia rapax (Comst.).
Myoporum serratum R. Br.
Hemiberlesia rapax (Comst.).
Nerium oleander L.
Lindingaspis rossi (Mask.).
Olea europaea L.
Aspidiotus hederae (Vallot).
Phoenix spp.
Aspidiotus hederae (Vallot), *Phenacaspis australis* Laing.
Pittosporum bicolor Hook.
Monaonidiella sp.
Prunus avium L.
Quadraspidiotus pyri (Licht.).
Prunus domestica L.
Quadraspidiotus ostreaeformis (Curt.), *Quadraspidiotus pyri* (Licht.).
Prunus persica L.
Quadraspidiotus pyri (Licht.).
Prunus serrulata Lindl.
Quadraspidiotus ostreaeformis (Curt.).
Quadraspidiotus perniciosus (Comst.).
Prunus triloba Lindl.
Quadraspidiotus pyri (Licht.).
Psoralea pinnata L.
Aspidiotus hederae (Vallot).
Pultenaea juniperina Lab.
Poliaspis exocarpi Mask.
Pyrus communis L.
Hemiberlesia rapax (Comst.), *Lepidosaphes ulmi* (L.), *Quadraspidiotus ostreaeformis* (Curt.), *Quadraspidiotus perniciosus* (Comst.), *Quadraspidiotus pyri* (Licht.).
Pyrus malus L.
Aspidiotus hederae (Vallot), *Aulacaspis rosae* (Bouché), *Hemiberlesia rapax* (Comst.), *Lepidosaphes ulmi* (L.), *Quadraspidiotus ostreaeformis* (Curt.), *Quadraspidiotus perniciosus* (Comst.), *Quadraspidiotus pyri* (Licht.).
Rhododendron sp.
Hemiberlesia rapax (Comst.).
Ribes nigrum L.
Aspidiotus hederae (Vallot).
Rosa spp.
Aulacaspis rosae (Bouché).
Sarothamnus scoparius (L.).
Aspidiotus hederae (Vallot).
Telopea truncata R. Br.
Aspidiotus hederae (Vallot).
Tulipa sp.
Aspidiotus hederae (Vallot).

FAMILY INDEX TO HOST PLANTS
(Cited as genera)

Apocynaceae.
Nerium.
Aquifoliaceae.
Ilex.
Araliaceae.
Hedera.
Cactaceae.
Cactus.
Casuarinaceae.
Casuarina.
Celastraceae.
Evonymus.
Compositae.
Bedfordia.
Cupressaceae.
Callitris, Cupressus.
Dennstaediaceae.
Blechnum.
Epacridaceae.
Astroloma, Epacris.
Ericaceae.
Arbutus, Erica, Rhododendron.
Euphorbiaceae.
Amperea.
Hippocastanaceae.
Aesculus.
Lauraceae.
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Acacia, Cassia, Davesia, Psoralea, Pultenaea, Sarothamnus.

Liliaceae.
Asparagus, Dianella, Diplarrena, Lomandra, Tulipa.
Monimiaceae.
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Myoporaceae.
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Myrtaceae.
Boronia, Eucalyptus, Eugenia, Leptospermum, Melaleuca.
Oleaceae.
Ligustrum, Olea.
Orchidaceae.
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Palmaceae.
Howia, Kentia, Phoenix.
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Rosaceae.
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Santalaceae.
Exocarpos.
Sapindaceae.
Dodonaea.
Saxifragaceae.
Anopterus.
Ternstroemiaceae.
Camellia.

ACKNOWLEDGMENTS

Particular thanks are accorded to Dr. D. J. Williams of the Commonwealth Institute of Entomology for the determination and confirmatory identification of many of the species listed in this publication. Thanks are also expressed to Miss J. D. Lane for assistance in the preparation of specimens prior to the making of slide mounts.

A NEW SPECIES OF BOECKELLA (COPEPODA: CALANOIDA) AND ADDITIONAL COMMENTS ON SOME OTHER SPECIES OF THE GENUS

By

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(With two text figures.)

SUMMARY

The new species, *Boeckella bispinosa*, is described and figured from Tasmanian material. The male fifth legs of *B. opaqua* Fairbridge, a Western Australian species, are figured and the original description supplemented. The female genital segment of *B. pseudochelae* Searle is figured. New records of *B. symmetrica* Sars, *B. minuta* Sars, and *B. major* Searle are given.

INTRODUCTION

The Australasian species of *Boeckella* were revised by Bayly (1964). In this revision a species believed to be new was figured, but not fully described or named because only a single specimen was available. Since then a few more specimens of this species have come to hand from Tasmania, and the opportunity is now taken to describe it. In addition, some material of *B. opaqua* Fairbridge, which was previously lacking, has become available, and this is figured and the original description supplemented. Finally some new records are mentioned, and a few comments made concerning the taxonomy of the females of *Boeckella*.

DESCRIPTION OF SPECIES

Boeckella bispinosa sp. nov.

Figs. 1A-1F

Boeckella sp. Bayly, 1964, p. 230, figs. 4E, 21A and 21B.

Material Examined

TASMANIA: Roadside pool four miles north of Campbell Town (altitude about 180 m), 9 ♂, 6 ♀, coll. J. Wilson, 20 ix 1963.

Material Examined Previously

WESTERN AUSTRALIA: Pond, Kelmscott, Perth, 1 ♂, coll. D. H. Edward, 5 ix 1960.

Type Material

Holotype ♂, allotype ♀, paratypes 4 ♂, 4 ♀; Aust. Mus. Reg. Nos. P15026-9. Type locality: Campbell Town, Tasmania.

Description of Female

Size.—Length inclusive of furcal setae, 2.30 mm (mean of 5); length to end of furcal rami, 1.97 mm (mean of 5).

Antennule length.—The antennules when extended backwards reach to the posterior edge of the genital segment. They are thus relatively shorter than in *B. minuta* and relatively longer than in *B. major* and *B. pseudochelae*.

Fifth legs.—Terminal exopodite segments with a total of seven spines.

Urosome (Fig. 1F).—Genital segment about 1.3 times as long as maximum width, asymmetrical with distinct excavation on left side anteriorly, genital operculum 0.42 times length of segment from anterior edge; urosome segment 2 about 0.6 times as long as wide; furcal rami about 2.3 times as long as maximum width.

Description of Male

Size.—Length inclusive of furcal setae, 1.65 mm (mean of 5); length to end of furcal rami, 1.40 mm (mean of 5).

Fifth legs.—Right distal protopodite segment produced inwards to meet median sagittal plane, projecting lobe attached to innermost edge distinctly mediad and proximal to point of attachment of right endopodite; right endopodite essentially 2-segmented and with segments of subequal length, sometimes with additional weak line of segmentation appearing in distal segment about one-third length from proximal edge, with two spines at distal extremity (invariably in the 10 specimens examined) (hence specific name), spines sometimes as long as distal segment and sometimes distinctly shorter, endopodite exclusive of spines extending 0.4-0.6 times distance along inner edge middle exopodite segment.

Inner distal corner left distal protopodite segment produced into a toothless lobe extending about 0.3 times distance along inner edge proximal exopodite segment; left endopodite very minute, no longer than protopodite lobe; middle exopodite segment (basal segment of exopodite claw) with small tooth on inner edge near proximal attachment.

Remarks

It is possibly more than mere coincidence that the only two collections found to contain this species were both made in September. It is also noteworthy that both collections were from small bodies of water. The Tasmanian habitat was

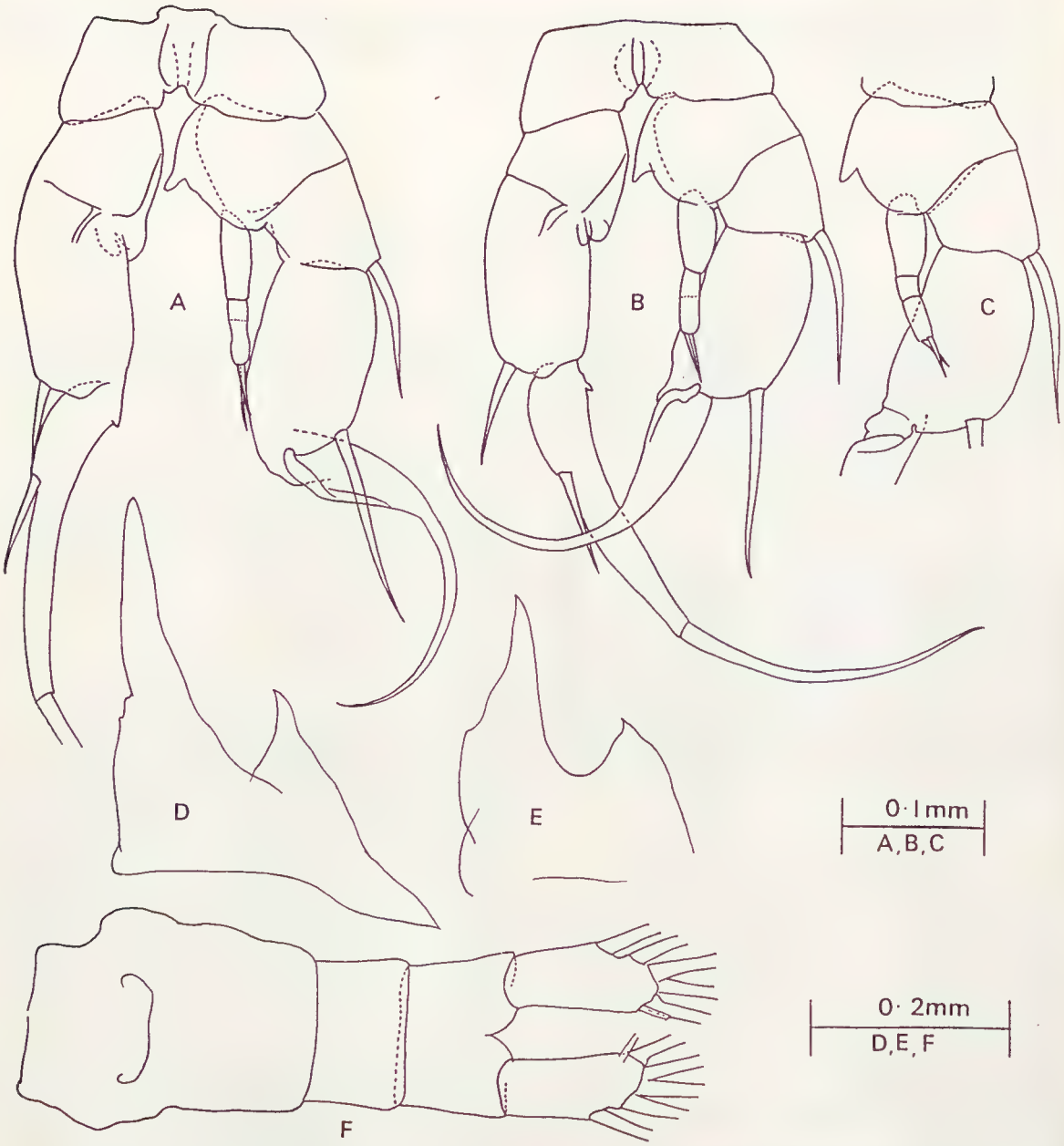

FIG. 1.—*Boeckella bispinosa*, sp. nov. A, B, posterior aspects of male fifth legs; C, posterior aspect of portion of male fifth right leg (A-C, all of different individuals); D, E, lateral aspects of right half of last metasomal segment of females; F, ventral aspect of female urosome.

described by J. Wilson (personal communication) as "a permanent or semi-permanent hole for stock watering".

The collection containing the 15 specimens of *B. bispinosa* contained no fewer than four other calanoid species. These were as follows (the number of specimens indicated in parentheses): *B. major* (28), *B. pseudochelae* (6), *B. triarticulata* (3), and *Calamoecia gibbosa* (3). The author cannot recall having previously found more than three different calanoid species present in the one freshwater collection. Of the accompanying species, *B. major* and *B. pseudochelae* are both noted by Bayly (1964)

as occurring in small bodies of water (ponds and pools). The possibility that *B. triarticulata* and *C. gibbosa* represented contaminants from an earlier collection seems rather unlikely in view of the nature of the immediately preceeding catch.

From data given above it may be calculated that the ratio (mean length females): (mean length males) for *B. bispinosa* is 1.40. This is rather high (cf. 1.30 (Bayly 1964) and 1.31 (B. V. Timms, unpublished data) for *B. minuta*, and 1.13 for *B. propinqua* (Bayly 1964)). It appears that the degree of size differentiation between the sexes is subject to a considerable amount of inter-specific variation and is a useful taxonomic character.

Surprisingly the only two records of this species come from opposite sides of the continent. It is evidently scarce yet widely distributed (at least with respect to longitude). Its distribution is somewhat similar to that of *B. symmetrica* which is common to south-eastern and south-western Australia but does not extend very far northwards (see Bayly 1964, fig. 23). Despite the existence of slight differences between the present eastern and western material (the length of the spines on the male right fifth endopodite, and the increased segmentation of this endopdoite in some of the eastern material) there is no hesitation in assigning it to the same species.

Boeckella opaqua Fairbridge

Figs. 2A-2D

Boeckella opaqua Fairbridge, 1945, pp. 25-38, Bayly, 1964, p. 226.

Material Examined

WESTERN AUSTRALIA: Granite rock pool, 56 miles east of Norseman at Smithania Rock, 10 ♂, coll. A. K. and J. Lee, 4 vi 1964; large granite pool, Yellowdine Rock, 1 ♂, 5 vii 1964; granite pool, east Yellowdine, 3 ♂, 5 vii 1964; High Pond, Yorkrakine, 1 ♂, 12 vii 1952; last three all coll D. H. Edward.

Discussion and Description of the Male Fifth Legs

Generally speaking the material examined agreed fairly well with Fairbridge's description. However, a few variations and a useful taxonomic feature not mentioned by Fairbridge were noted.

Fairbridge described and figured the right endopodite as if it were distinctly 2-segmented. However, in none of the 15 specimens examined was this the case. In 12 specimens this endopodite was completely unsegmented, and in the remaining three it was weakly 2-segmented. It should thus be described as 1-2-segmented. In the material examined this endopodite extended less than halfway along the inner edge of the middle exopodite segment.

Fairbridge stated that the lobe attached to the inner distal corner of the left distal protopodite segment "is not denticulated". However, when the present material was examined under higher magnifications distinct serrations were in evidence along the inner edge of this lobe (see Figs. 2C-D). As described by Fairbridge, the left endopodite was invariably 2-segmented in the present material. It extends almost to the end of the proximal exopodite segment and is thus unusually well developed (cf. *B. symmetrica*).

There is another feature, not previously stressed, that appears to be more distinctive of this species than any single feature mentioned above. This is the nature of the spine on the outer edge of the left middle exopodite segment (equivalent to the basal segment of the left exopodite claw). It is exceptionally long and usually extends to the distal extremity of the segment or just beyond (in two specimens examined it was somewhat short of the distal extremity). Another peculiarity is that this spine scarcely diverges from its segment but remains closely adpressed to the outer edge. This feature is not in itself completely diagnostic of this species but in most cases separates it from the closely allied species *B. symmetrica* (in this species the spine usually extends less than 0.8 times the distance along the segment). It should be pointed out that in *B. opaqua* the segmentation between the middle and distal segment of the left exopodite is not uncommonly weak and sometimes absent giving rise to an apparent 2-segmented condition.

In *B. symmetrica* the right endopodite is usually distinctly longer than the left one, but in *B. opaqua* the two endopodites are of sub-equal length.

Remarks

It will be noted that the habitat of the specimens examined corresponds exactly with that described by Fairbridge viz "shallow granite pools".

THE IMPORTANCE OF THE STRUCTURE OF THE GENITAL SEGMENT IN THE TAXONOMY OF FEMALES

In my earlier revision of the genus (Bayly 1964) the taxonomy of the females was largely neglected. Although it was admitted that the structure of the genital segment was subject to specific variation, difficulties in exploiting this taxonomically were pointed out. Perhaps the chief of these is the essentially non-meristic nature of much of the variation, and the difficulty of concisely and quantitatively describing the complex shapes involved. Despite my earlier reservations, I am now inclined to believe that a detailed comparative study of the genital segment represents the best hope for an eventually satisfactory taxonomy of the females.

In separating the females of the several species in the mixed collection containing *B. bispinosa* I was impressed by the differences between the urosomes, and especially the genital segments, of *B. bispinosa* and *B. pseudochelae* (cf. Figs. 1F and 2E). As shown by Figure 2E, the female genital segment of *B. pseudochelae* is subcircular or about as long as wide (cf *B. bispinosa*, 1.3 times as long as maximum width). The anterior recess on the left side of genital segment of *B. bispinosa* is also characteristic and contrasts with the smooth convexity of both sides in *B. pseudochelae*. The genital segments of *B. bispinosa* and *B. pseudochelae* may be compared with those of *B. hamata* Brehm, *B. geniculata* Bayly and *B. montana* Bayly which are figured by Bayly (1964). The construction of a satisfactory dichotomous key to females of species other than *B. minuta* (which is readily identified by the fifth legs) on the basis of genital segment structure would not be easy. The direct successive comparison of material in hand with figures of the genital segment would probably be the most reliable method of establishing identity.

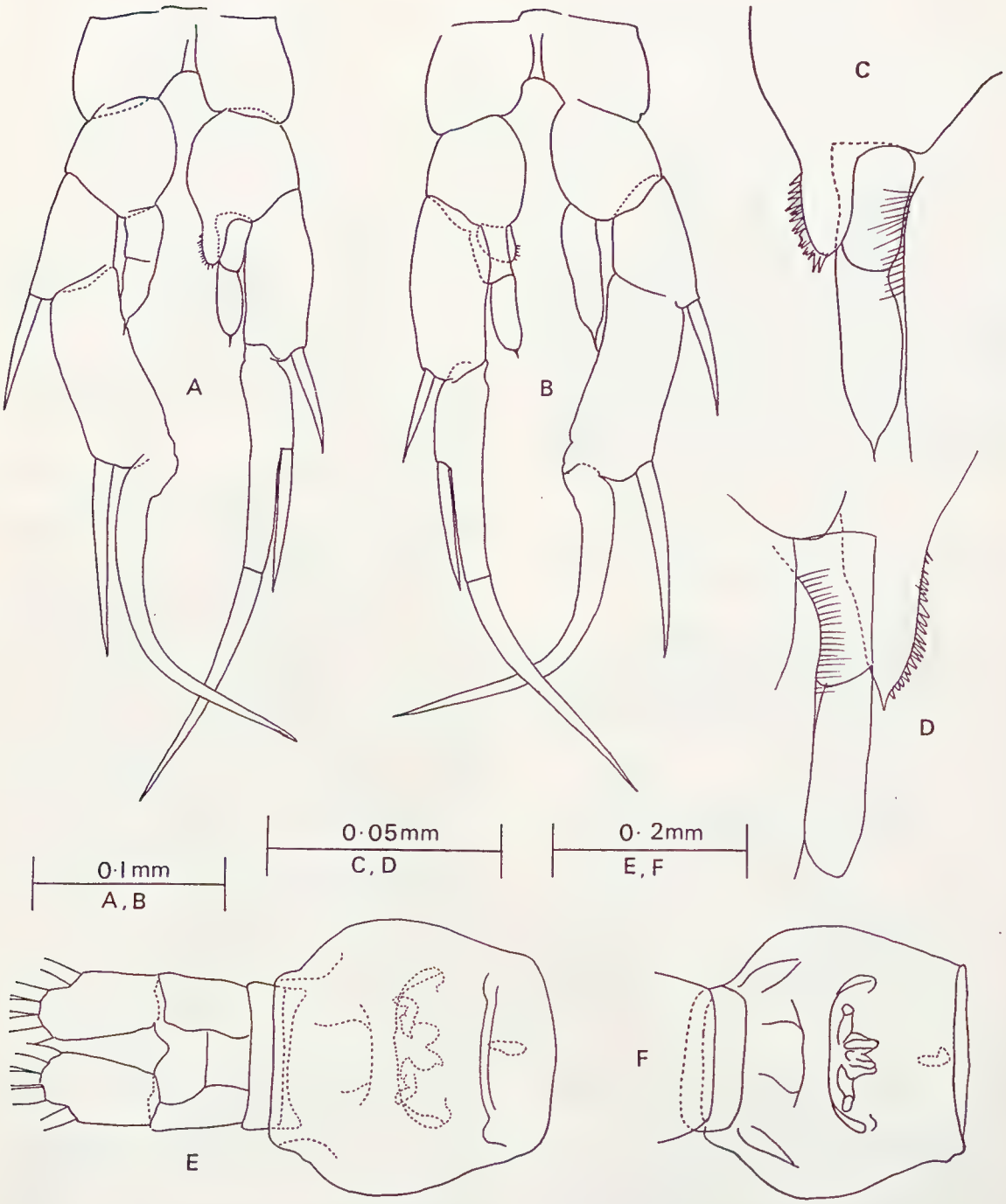

FIG. 2.—A-D, *Boeckella opaqua* Fairbridge; E, F, *B. pseudochelae*. A, B, anterior and posterior aspects, respectively, of male fifth legs; C, D, anterior and posterior aspects, respectively, of portion of male fifth left leg including endopodite. E, dorsal aspect of female urosome; F, ventral aspect of female genital segment.

NEW RECORDS

Since publication of the revision (Bayly 1964) a few noteworthy records, which extend known distribution limits, have come to hand. Some of these were incorporated in a recent paper (Bayly 1966, p. 131) dealing mainly with *Diaptomus*, others are as follows:—

(1) *Boeckella symmetrica Sars.*—Specimens collected from a large farm pond at Papatoetoe, Auckland, by Miss M. H. Barclay proved to be this species. This is the first record of *B. symmetrica* from New Zealand. This means that six species of *Boeckella* are now known to occur in New Zealand, and that four species are common to Australia and New Zealand. *B. symmetrica* is thus even more widespread than previously thought, and the earlier map (Bayly 1964, fig. 23) showing its distribution should now be amended. The possibility now arises that Henry's (1924) record of *B. triarticulata* from the vicinity of *Auckland* represented a misidentification of *B. symmetrica* not *B. propinqua*. There is a close structural similarity between B. *symmetrica* and *B. triarticulata*.

(2) *B. minuta* Sars.—This was collected by the author from a farm dam at Yarra Glen near Melbourne in March 1964. This is the first record of this species from Victoria since early this century. An earlier remark (Bayly 1964, p. 201) may not, therefore, have much significance.

(3) *B. major* Searle.—This species was collected from two high altitude lakes (Island Lake and a small unnamed lake about half a mile away) near Cooma, New South Wales, by Dr. W. D. Williams in August, 1964. It was also collected (together with *B. pseudochelae*) by the author from shallow, partially frozen, pools between Shannon Lagoon and Great Lake, Tasmania, in August 1965. Most recently (May 12, 1966) it was collected from a shallow pool adjacent to Christmas Bay, Great Lake, by Mr. P. A. Tyler.

B. major and *B. pseudochelae* seem to occur in small bodies of water mainly during the period late autumn to early spring. This is probably true also of *B. bispinosa*.

ACKNOWLEDGEMENTS

I wish to thank Mr. J. Wilson, Butler's Gorge, Tasmania, and Dr. D. H. Edward, University of Western Australia, for collecting the material upon which this paper is based.

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————————, 1966.—The Australian species of *Diaptomus* (Copepoda: Calanoida) and their distribution. *Aust. J. Mar. Freshwat. Res.* **17**: 123-34.

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PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA, VOLUME 101.

ON RISSIKIA AND MATAIA PODOCARPACEOUS CONIFERS FROM THE LOWER MESOZOIC OF SOUTHERN LANDS

By

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(With two plates and 15 text figures.)

ABSTRACT

The genus *Rissikia* gen. nov. consisting of leafy shoots and detached pollen and seed cones is described, with two species, *R. media* (Tenison Woods) com. nov. and *R. apiculata* sp. nov. Also described is *Mataia* gen. nov. with one species *M. podocarpoides* (Ettinghausen) com. nov. These are all ascribed to the Podocarpaceae, and the evolution of the Family, particularly of the epimatium is discussed.

INTRODUCTION

The two conifer shoots included in the following description are believed to be podocarpaceous, and indeed to throw light on the history of some organs in the Podocarpaceae, in particular, the nature of the epimatium. It has for long been considered (e.g. Gibbs 1912 and Florin 1944) that the epimatium is a modified seed scale complex but how it was modified has remained somewhat obscure. The fossils discussed herein offer one explanation. Much however, is left aside for the present: for example, the relationship of the earliest podocarps to the *Voltzia* group of conifers; the evolution in the non-epimatial cone; and the nature of the male fertile branch. These questions I hope to take up with the aid of other conifers both older and younger than those considered here.

Material is referred to under its numbers in Museum collection, by whoever it was collected.

DESCRIPTIONS

Family PODOCARPACEAE

Genus **RISSIKIA** nov.

Type species: *R. media* herein.

Diagnosis. Coniferous plant bearing regularly abscissed (? deciduous) foliar spurs. Spurs about 6 cms. long and of strictly limited growth, bearing small scale leaves at the base, and thirty or more large adult leaves. All leaves spirally inserted; either projecting spirally or in two lateral ranks. Leaves thick, rhombic in section or bilaterally flattened, about 0.75 cms. wide; bases decurrent but not or scarcely contracted, apices acute, sometimes assymetrical and terete. Cuticle thin (0.5μ—2μ), showing similar cellular pattern over the whole leaf. Cells more or less rectangular, set in regular longitudinal rows, and sometimes papillate, cell outlines sometimes sinuous, or pierced by small holes. Stomata in four diffuse zones, a zone per flank. Stomata lying in one to three rows per zone, separated from one another at least by a shared encircling cell, usually by more cells; most often monocyclic with four subsidiary cells, two lateral and two terminal, unmodified except by position. Stomatal pit rectangular, shallow, usually overhung by two to four solid or hollow cutin projections borne on surface of subsidiary cells. Guard cell surface slightly concave inwards, feebly cutinised, aperture about two thirds as long as pit.

Pollen cone rounded in outline, about 1 cm. long and 0.5 cm. wide in the middle, borne on a stout curving stalk about 2 mms. in diameter, showing remains of scale leaves. Cone consisting of (estimated) 25 units, each unit consisting of connective, peltate scale, and two pollen sacs. Connective about 0.75 cm. wide, inserted on to peltate scale a little below mid point of the scale, and bearing the two pollen sacs along its whole length, attached to under surface of connective. Peltate scale not radially symmetrical, rounded or slightly triangular in outline, about 1.5 mm. wide and 2 mm. high. Pollen sacs of thick wall, not attached to the scale. Outward surface of scale and pollen sac cutinised, probably also connective and cone axis, (cuticle always thin 0.5μ or less). On scale cells nearly equidimensional, set in rather irregular longitudinal rows, and with a few longitudinally orientated stomata, like stomata on leaves, but only very rarely with cutin projections over stomatal pit. On pollen sac, connective and cone axis cells elongated, in rows, stoma absent.

Pollen disaccate, striate, leptomatous, of total width about 50μ with rather thin extine. Corpus rounded in polar views, sacci slightly displaced distally. Striae showing as three to ten, mostly four to six, clefts with (presumed) intextine becoming visible. separated by bars of thickened exoextine. Clefts mostly narrow (about 2μ), but up to 10μ wide, when narrow occasionally forked. Thickened bars about 5μ (4-10μ) wide, surface more or less smooth, or showing minute pitted ornament. Striae concentrated on the cappa. Corpus about 35μ in diameter, about 30μ deep, widest part lying near the proximal surface. Sacci with proximal roots inserted at (or to either side of) widest part of corpus, as deep as corpus, and about 10μ high; rarely nearly continuous round corpus in equatorial plane. Ornament on sacci reticulate, brochi sometimes elongated at right angles to cappula long axis; brochi about 5μ long and 3μ wide. Form of ornament as in living conifers.

FIG. 1.—*Rissikia apiculata*, A-D: *R. media*, E-J.
A-J: Foliar spurs, all x 1.
A: 13036, Univ. Sydney.
B-J: Australian Museum, F51981, 51957, 59980, 51964, 51975, 51961, 51968, 51963.

Seed cones terminal on leafy branches; branches up to 1.5 cms. long (total length unknown) leaves on branches rhombic in section, up to 4 mm. long and 1 mm. wide, grading into bract scales. Whole cone spike-like in form, about 3 cms. long, bearing 15-25 units spirally arranged. Each unit consisting of bract subtending the cone scale and the stalked seeds (axillary short shoot, flower or seed scale complex). Bract trifid, with denticulate margin. about half as long as cone scale. Cone scale (seed scale complex, or flower in other terminologies) consisting of short axis, thick, possibly round in section, about 0.5 mm. long; axis produced into three lobes, rounded, denticulate, or produced into a long pointed apex. On abaxial surface, lobes showing two longitudinal ridges, possibly with vascular tissue. Seeds (ovules) inverted, borne at end of stalk 0.75 mm. long, and 0.2 mm. in diameter, round in section. Stalk inserted towards base of seed scale lobes, but otherwise free from lobe. Two to six seeds per cone unit, but probably only one or two reaching maturity. Seeds about 0.75 mm. long, 0.5 mm. in diameter, round in section.

Cuticle of bract about 1μ thick on abaxial surface, thinner on adaxial, showing elongated rectangular cells in rows, but no stomata. On lobes of cone scale, abaxial cuticle, 1μ-1.5μ thick, showing more or less equidimensional cells in rows, but over ridges, cells longer and narrower. Stomata few, as on the leaf, with or without cutin projections, cell outlines as on leaf. Abaxial surface with extremely thin cuticle, showing rows of more or less rectangular cells and no stomata. Cuticle of seed stalk showing obscure elongated cells. Cuticles of seeds consisting of cutinised integument, and projecting possibly hollow cutinised nucellar beak at micropylar end. Nucellus probably free from integument to its base. Further detail unknown.

Description and Discussion. (1) *Origin of material.* The material comes from Burnera Waterfall, Upper Umkomaas, Natal. This locality falls within the Molteno, the lowest member of the Stomberg Series. The Molteno has been considered Middle Triassic, but the discovery of sauropods in it (Dr. J. Cosgriff pers. comm.) places it in the Upper Triassic. A very few shoots, including the holotype of *R. media* come from other places e.g. the shoot shown in Pl. 2F, and Fig. 1A.

(2) *Ascription of organs to each other at the generic level. Rissikia* is represented by two suites of fossils at Burnera. *R. media* consists of 30 foliar spurs, four seed cones and probably two pollen cones: *R. apiculata* has 15 foliar spurs, two seed cones and no pollen cones. The corresponding organs of the two species are so similar that I think it is almost certain that we are dealing with two species of a single genus. In my collection there are no other conifer macrofossils (out of over 500 specimens). Even at Burnera therefore, *Rissikia* is still an uncommon fossil.

The conclusion that the separate organs belong together is reinforced by the resemblance between the cuticles of the separate organs. Though there is uncertainty at the specific level, taken as a group, the form of the cell outlines, papillae and especially, stomata is the same in all. Though most of the rather few stomata on the cones show no cutin projection over the stomatal pit, in this matching a large minority of leaf stomata, some do show projections, agreeing exactly with some of those found on the leaf (Pl. 2B and Fig. 6F).

The stoma of *Xylopteris elongata* (Carruthers) Frenguelli is slightly like the stoma of *Rissikia* (see Jones and de Jersey 1947: Pl. 3 Fig 1, and Townrow 1962 b: Fig. 2) but can be easily told apart, for it is dicylcic and the stomata do not lie in more or less regular rows.

(3) *The foliage.* Eight foliar spurs of *R. media* are complete, or show the base, and two of R. *apiculata.* All these show a clean break at the base, with what looks like an abscission scar (Fig. 4A, B, D, G). There is no specimen of a foliar spur showing an eroded base. At the apex the leaves overlap the apex, and a bud cannot be seen (Figs. 4C, H), but one specimen which may have grown on is shown in Pl. 2H. These appearances can be matched in, *Metasequoia glyptostroboides* Cheng and Hu or *Podocarpus imbricatus* Blume, (juvenile form) and indicate that the fossils are foliar spurs, regularly shed, and of strictly limited growth (cf. Fig. 2G *P. imbricatus*). Hence, even though the long shoots are unknown, we can with some assurance, reconstruct the *Rissikia* branching pattern. The ultimate shoots of the tree were presumably like the young shoots of *Podocarpus* Section Dacrycarpus.

It is not clear whether the shoots were shed annually, as in *Metasequoia* or at longer intervals as in *Podocarpus imbricatus.* The very thin cuticle and scarcely sunken stomata recall *Metasequoia* (Figs. 10G, H), and suggest that *Rissikia* may have been deciduous also.

The shoot base itself is swollen and the scar heart-shaped as if was in two parts (Figs. 4A, F). It has not, however, been possible to make out the vascular supply. On this swollen portion there are three to six small flat scale leaves, attached in the manner of bifacial leaves, and about 0.5 mm. long, they pass rapidly but continuously into the adult sort of leaves. Such small leaves again can be matched in *Metasequioa* and *Podocarpus* species (Section Dacrycarpus) (Fig. 2G) and were, in the fossil, presumably a sort of bud scale. They are also seen in *Acmopyle* Bgt. and Gris. It appears therefore, that unlike some podocarps, (Wardle 1962), *Rissikia* had some definite structures protecting the spur bud, though not many of them. The leaves are spirally inserted, strongly decurrent but are dealt with in detail under the species. Towards the shoot base the spur axis is (now) more or less flat, but at the top distinctly angled, because of the large decurrent leaf bases (Fig. 3G). On some of the largest shoots the axis shows transverse ribs; these are wholly internal, and of unknown nature.

The cuticle is always thin, but often of about the same thickness all over the leaf, and in both species shows cells in longitudinal rows (Pls. 2A, C; Fig. 5). Judging from small pieces of cuticle only, the stomata density is about the same on both surfaces, or pairs of flanks, of the leaf. Figs. 5A-E show the disposition of the stomata in the zones, and Pd. 2B a stoma with cutin projections. In only about one stoma out of a hundred are the lateral subsidiary cells divided. Encircling cells are normally absent. The stomatal pit is rather

FIG. 2.—*Rissikia media A, B; Elatocladus planus, C. D; E. australis,* E; *Podocarpus lawrencei,* F; *P. imbricatus* (juvenile) G; *P. dacrydioides* H.

A: The holotype, x1, MacLeay Mus. 102.
B: Foliar spurs from Gilgandra, N.S.W., x 1, Australian Museum 42354.
C, D: Parts of two foliar spurs, x 1, University of Tasmania.
F: The holotype, x 0.5 drawn over Kew Negative 6192, by courtesy of the Director, Kew Botanical Gardens.
G: A shoot system showing long and short shoots, x 0-5 Fiji Forestry Service.
H: Part of a shoot showing pinnate branching and variable leaves, x 0-5.

constant in shape, but the projections overhanging it vary. In general, they are best developed on the thicker cuticles, and are missing altogether on some leaves, especially some with a very thin cuticle. This may be the explanation for their absence on the extremely thin cuticles on the cones. The projections are dealt with in detail under the species, but they form in *R. media* solid cutin lappets, and in *R. apiculata* hollow papillae. In structure the stomata approach rather closely to the (somewhat unusual) stomata seen in *Microstrobos* Garden and Johnston and *Microcachrys* Hook f. (Florin 1931), and especially so, when lappets on the terminal subsidiary cells are missing (Fig. 5D). They also resemble the stomata of *Saxegothea* Lindl. (Fig. 13B). The guard cells are very thinly cutinised, but sometimes cutinisation of the dorsal guard cell surface under the subsidiary cell can be seen (Fig. 6D).

(4) *The pollen cone.* The pollen cone is represented by only two specimens each having part and counterpart. As discussed below (p. 119) the cone is thought to belong with *Rissikia media.* The incomplete curving stalk is about 2 mm. wide at the base (i.e. about the width of a foliar axis above the basal swelling), but is seen only in short length on one cone (Fig. 8B). On the pedicel there are more or less broken fragments of tissue (Fig. 8B) which look like the remains of small flat leaves, as on the foliar spur and at the base of the cone there are two (possibly three) larger leaves about 1.5 x 0.25 mms., more like a cone unit, but sterile (Figs. 7C, 8B, cf. Fig. 8A of *Dacrydium franklinii* Hook f.). The cone axis is about 1.5 cms. wide about half way up the cone, and counting the scars on it, and the visible units gives the estimated 25 units per cone. The connective, like the cone axis, is somewhat wrinkled (Fig. 7E), suggesting it may have been thick; it shows strong cellular striae, agreeing with the cells seen on some cuticles, but it was not possible to obtain a preparation of cone axis or connective only. At the end, the connective flattens out into a triangular structure, as seen from above (Fig. 7E), and is attached to the peltate scale rather nearer the base of the scale than the top. Seen from outside (Figs. 7D, E) the scale shows, in the appropriate position, a depressed area, interpreted as the area of attachment, diamond shaped, about 1 mm. long and 0.5 mm. high. No scale is complete, Figs. 7D, E shows parts of several scales in various views. The surface shows cellular striae, and at the top edge a slightly ragged appearance, caused, apparently, by rows of elongated cells, much as in many living conifers. Each scale overlaps about half the one above (Pl. 2I). There are almost certainly only two pollen sacs. In several places two can be seen at different levels (Fig. 7E), but not more than two. The base of the scale overlaps the pollen sacs, but, unlike living podocarps, the scale and pollen sacs do not seem to be joined: for there is a distinct gap, sometimes containing, mud, between scale and pollen sac. This situation is seen in various fossil conifers, and in *Dacrydium laxifolium* Hook. f., there is an approach: a small flap of tissue partly overlaps the pollen sacs (Fig. 7F). I do not know how many cell layers compose the pollen sac wall, but it is probably several in the two specimens seen.

The cuticle is described in the diagnosis and shown in Figs. 6C, 10F). The details, and stomata, are like those on a thinly cutinised leaf of *R. media.*

(5) *Pollen.* The pollen appeared mostly as single grains or groups, sticking to pieces of cuticle prepared from the pollen cones. One preparation, however, showed a fragment of pollen sac, still full of pollen. There are many other sorts of pollen in the preparation. The sort described is thought to belong with the cone because (1) the full pollen sac contained grains of this sort and (2) the grains regarded as strangers were fewer in number, and appeared only as single grains, not groups. Only one grain showed what might be a colpus, but it was, I think, a tear: the grains are therefore described as leptomatous, especially since lateral longitudinal views showed an intact cappula (Fig. 9B). The striae are not very striking, and before staining, scarcely to be seen, but they are present with such regularity that I have no doubt they are genuine. I do not have a grain (out of about 80) compressed in such a way as to show the striae in optical section (cf. e.g. Leshik 1955, pl. 8 figs. 4 and 5), but in polar and lateral longitudinal views they look so like other striate grains that they are described in the same terms. There is, however, much variability. Five grains showed no striae at all (Fig. 9C). Most showed four to six bars of thickening, separated by more or less narrow clefts, and some 20 grains showed more or less wide clefts (cf. Pl. 1H and Figs. 9E, D), and about the same number showed up to 10 very narrow and sometimes forking clefts (Pl. 1F, Fig. 9A). In any case, the central two to four bars of thickening were the most stained—i.e. the thickest.

In polar view the corpus was always more or less round, but varied in lateral longitudinal views (Figs. 9B, D and Pl. 1F, H), as did the insertion of the sacci, though this was always close to the widest part of the corpus. The extine is probably thin (about 3μ) as seen in folds, and the saccus roots clearly visible. The other features are given in the diagnosis, and L.O. analysis shows the ornament to be of the usual conifer sort. A small number of grains show a crack (or very thin place) in the extine on the proximal surface, about in the middle (Fig. 9C). The feature is, however, variable in form. It is, I imagine, of the same nature as the similar looking crack shown by Klaus (1963 e.g. pl. 13) in his striate grains. Klaus regards it as a monolete mark, indicating that the pollen grains were produced in a planar tetrad, and I am inclined to agree (cf. also Balme 1963). However, I am not quite convinced, in *Rissikia,* that the crack is original, it is too seldom seen and too variable (there is also variation in Klaus' specimens); it might be a result of compression, or of Schultze's maceration.

(6) *The seed cone.* The seed cones are spike-like in general outline (Pl. 1A, B, Figs. 8C, D, E) having 12-25 units (bract plus cone scale) disposed up a long axis, and though the units do overlap, they are well separated unlike, e.g. *Pinus* L. or *Cupressus L.,* where the units are crowded together. The basic structure is as for all conifers, namely, an axis bearing leaves (the bract scale) in the axis of which arises short shoots with seeds (cone scale; or the seed scale complex or flower in

FIG. 3.—*Rissikia media*, A, D, E, G; *R. apiculata* F; *Elatocladus australis* B; *E. planus*, C.

A, B, E-G: Parts of foliar spurs, showing insertion of leaves and their variation in form, all x 7. B, Australian Museum 50192; A, E, F, G, Australian Museum, F 51965, 51964, 51976, 51967; C, D: Leaf apices x 14, C University Tasmania; D, Australian Museum, E 51960.

Florin's terminology). In both species the cone is terminal on a more or less short length of leafy axis, broken off unevenly below, unlike the foliar spurs (Figs. 8C-E), and hence presumably not abscissed. The greatest length of shoot seen was 1.25 cms. (Fig. 8C) and by analogy with several fossil and recent conifers. I imagine that it was probably not much longer originally. The leaves on this axis are nowhere seen really plainly, Fig. 8C shows the best specimen, and on it the leaves are rhombic in section, appearing thick about the middle, tailing away to a narrow margin and apex. They were, thus much like small closely appressed leaves of *R. apiculata* foliar spur. I could not see where they became trifid like the bracts.

(7) *The cone unit.* It was difficult to obtain satisfactory transfers of the bract scale. Fig. 8H shows the best, and from it the bract is seen to be trifid. Other specimens (Figs. 14D, E) are less clear, but in the better of these, three parts of the bract can be seen.

The cone scale with its subtending bract is sometimes presented face on to the observer (Figs. 8F, G), more often it is curved round the axis, and presumably this was its form in life (Figs. 8I). When seen face on, the cone scale is also seen to be trifid. It consists of three lobes joined below, but not always quite at the same level (Fig. 8F). one, often the central one, slightly overlapping the others. These lobes are of thick substance, and are themselves either slightly crenulate (Figs. 8F) or entire (Fig. 8G) sometimes produced to a long point (Pl. 1D, Figs. 14D, E). Seen compressed laterally (Fig. 8I) the common stalk of the three lobes, was only a little less thick than it was wide when compressed vertically. Presumably, therefore it was more or less terete.

The seeds (or ovules, *seeds* is used to cover both) lie on the adaxial surface of the lobes, appearing as raised areas (Figs. 7F, G, H), From the lower end of the seeds, a low ridge runs towards, and finally merges with the stalk of the lobe (Fig. 7G). This is interpreted as a seed stalk. In some specimens (Pl. 1D and Fig. 8G) the seed and its stalk could be broken up from the lobe surface revealing a very fine layer of mud between the two. Furthermore, although it proved impossible to obtain cuticles of an entire lobe with its seeds, some seeds, on maceration, showed a broken tube of cuticle emerging from one end (Pl. 1G and Figs. 9H-J) and another specimen (Fig. 10D) shows the adaxial surface of a lobe, and lying on it (actually adhering to it) is a tube of cuticle. This tube is shown to be separate from the lobe surface by a large spore, lodged between tube and lobe surface. This means that the seeds were borne on their own little stalks, not adnate to the cone scale. These stalks are all one can call a megasporophyll.

The seeds are minute, some 1.75-1 mm. long and 0.25-0.5 mm. wide, their stalks being about 0.2 mms. wide. Cuticle preparations show the micropylar apparatus at the same end of the seed stalk (Figs. 9A, H-J), hence the seeds were inverted. There are one or two seeds per lobe of the cone scale, but it is not unusual to see only one large seed (or its impression in the matrix) per cone unit, so that it is probable that not all the seeds ripened, or were pollinated. Nothing is known directly of the internal structure of the cone scale. However, the abaxial surface of each lobe of the cone scale is raised in two ridges (Figs. 8I, 13D), and on the cuticle these ridges correspond to rows of more or less elongated cells (Fig. 9K). These features, in a leaf, mark the position of veins, and it is therefore possible that each lobe contained two vascular traces.

(8) *Cuticles.* As with the pollen cone, cuticle could only be prepared in small pieces, though as far as possible (which was not far) different organs were macerated separately. All parts are cutinised, but stomata are extremely rare, only eleven were seen altogether. By analogy with living plants, it is probable that the cone was not actively photosynthetic, or we might expect more stomata.

The bract shows a cuticle essentially similar on both surfaces (Fig. 10A), though the adaxial cuticle is extremely thin. The cells on the bract were elongated and, mostly, in fairly definite rows. Very few stomata at all were seen here and no differences in cell size could be seen distinctly. On the lobes of the cone scale the cells were different. The abaxial surface in both species was fairly thick (1μ or more) and showed cells distinctly and very rare stomata. The adaxial cuticle was so thin that by transmitted light it was invisible before staining, probably 0.5μ or even less. No stomata were seen on it, (Figs. 6C, F, 10D).

A feature of both species is a halo of staining material forming, as it were, a margin to the cell outline. This was not always present (Fig. 10B), and I suspect it is a result of slight under-maceration. In *R. media* the cell outlines were pierced by small holes, such as in some living conifers, e.g. *Microstrobos* (see also Florin 1931).

The seed cuticles were not seen satisfactorily. Despite repeated efforts with rather scanty material, I failed to obtain a seed with cuticles intact; by the time the internal substance was macerated, the very delicate cuticles were destroyed. The best specimens as shown in Figs. 9H-J. Another unfortunate fact is that no pollen could be seen clearly though there are objects that may be pollen in the micropyles. On maceration a great quantity of material dissolved out from the integument region. Possibly therefore the integument was thick, though whether woody or not, is not known.

Within the seed, several layers could be seen. The most disinct lay well inside and away from the micropyle (Fig. 9H) it presumably is the megaspore membrane. In two seeds (Fig. 9I, the other, Pl. 1G was unfortunately damaged) a further line outside the megaspore membrane could be seen, extending from the end of the nucellar beak (see below) to the seed base. This I take to be the outer edge of the nucellus, and since it can be seen so far, it probably indicates that the nucellus was free to the base (cf. Harris 1931). At the micropyle itself four seeds (representing both species) showed a similar appearance. The cutinised outer surface of the integument ends as a sort of collar, and from within this collar there is a further tube of cutin, which, as just noted is continuous with a line lying between the outside edge of the seed and megaspore membrane (Figs. 9H-J). The simplest explanation is that this is a nucellar beak, pro-

FIG. 4.—*Rissikia media*, A, D, F-H; *R. apiculata*, B. C.; *Elatocladus planus* E. A, B, E-G: Bases of foliar spurs, showing swelling, and small leaves not bilaterally flattened, x 7, F x 2 Australian Museum, F51960, 51976, 51969, 51961; D: A young foliar spur enclosed within the small protective leaves, x 10, Australian Museum F 51976. C, H: Apices of two foliar spurs, no bud to be seen, so growth presumably limited, x 7. C, Australian Museum F51976; H, F51961.

jecting out from inside the micropyle. The beak is now seen as a tube of cutin, and I suspect it was hollow in life, but in default of pollen inside it, or a cutin lining, cannot prove this point. The seeds were about the same width whether compressed dorsi-ventrally (Figs. 9H) or laterally (Pl. 1G). This indicates that they were round in section.

Unlike some conifers, such as *Voltziopsis* Potonié isolated cone units do not seem to occur; at any rate at all frequently. Probably the cone was shed as a unit, and did not disarticulate. This is what happens in *Podocarpus andinus* if the ovules are not pollinated.

The name is for Mr. and Mrs. U. Rissik, Johannesburg and Vergelegen, to whom I am indebted for much hospitality.

Rissikia media (Tenison Woods) com. nov.

Pls. 1A, B, E. F. H; 2A-C. Figs. 1E-J; 2A, B; 3A, D, E, G; 4A, D, F-H; 5A, B; 6A-D; 7C-E; 8B, C, E-J; 9A-E, H, I, K; 10A, C, D, F; 15A, B.

1883 *Taxites medius* Tenison Woods, p. 160-161, pl. 9, fig. 3. Impressions, localised as "Ipswich".

1927 *Voltzia* cf. *liebiana* duToit non Goeppert, p. 393, pl. 21, fig. 3. Imperfect specimen from the Molteno.

1935 *Voltzia* cf. *heterophylla* Carpentier non Brongniart, pl. 4, fig. 4 (good complete shoot), ?pl. I, figs. 6, pl. 4, fig. 5. Lower Triassic of Madagascar.

?1935 *Voltzia* cf. *heterophylla* Carpentier, pl. 5, fig. 8. Imperfect specimen.

(I have not had access to the works of Geinitz or Szajnocha referred to by Florin 1940 p. 33).

Holotype. MacLeay Museum No. 102: see Tenison Woods 1883 pl. 9, fig. 3, and Fig. 2A.

Locus typicus. Burnera Waterfall, Upper Umkomaas, Natal: Molteno, Upper Triassic.

Diagnosis emended: Plant with foliar spurs about 8 cms. (3-11 cms.) long bearing thirty or more bilaterally flattened leaves of thick substance, about 1 cm. long (0.3-2.5 cms.) and 3 mms. (1.0-5 mms.) wide, twisted into two rows up the shoot. Leaf apex sometimes asymmetrical. Leaves 0.2-0.5 cms. apart. Cuticle of leaf often thicker on one pair of flanks than the other, cell outlines straight, about 1.5μ 1.0μ-2.5μ) thick, rather rarely pierced by small holes. Stomata in rows, separated by terminal subsidiary cells, and up to five other cells, and by at least two cell rows and the lateral subsidiary cells. Guard cells slightly sunken, normally overhung by solid cutin lappets on the subsidiary cells, but lappets sometimes absent. Pollen cone 1 cm. long and 0.5 cms. wide (see generic diagnosis), cell outlines pierced with holes at least on outward surface of scale. Seed cone, 2.5-6 cms. long with 15 to 20 units per cone, units about 0.3 cms. apart. Trifid bract scale about 3 mm. long, cone scale about 6 mm. Lobes of cone scale blunt, thick, sometimes showing shoulders. Two seeds per lobe of cone scale. Seed about 0.75 mms. long and 0.5 mms. wide (0.3-1 mms. x 0.2-0.75 mms), egg-shaped, narrow. Epidermal cells of bract scale somewhat elongated, about 40μ x 60μ; on cone scale more or less equidimensional on both surfaces, about 50μ. Cell outlines rather narrow, 1.0μ or more thick, pierced by holes. Stomata slightly sunken, and surface of guard cells convex inwards.

Description and discussion (1) *General.* The Waterfall specimens are finely preserved, but difficult to transfer. On treatment in HF, the matrix goes to a cheesy mass, tougher than the plant substance, that has to be carefully brushed off. The plant material sticks hard to the rock, and is difficult to remove to obtain cuticles.

As with all the thick organs considered here, the cones split more or less down the middle. This is most important. It means that to see the outside of the cone, a transfer must be made. It also means that to obtain an idea of the whole fossil, part and transfer of counter-part must be put together. Further, there is the danger of overlooking features when only part or counterpart is available.

The leaves are spirally inserted (possibly 3/8) but like many conifers are modified into two lateral rows, apparently by twisting, that is, unequal growth of the leaf base. The leaves, however, are flattened so that they are edge on to the shoot, just as in *Podocarpus imbricatus* (cf. Figs. 3A, E, G). Thus they are bilateral, each apparent surface being morphologically, half the upper and half the lower surface. The leaves, are, however, thicker than seems to be normal in living podocarps with bilateral leaves, some (Fig. 3A) showing several ridges, presumably caused by compression of a thick structure, along their length. At their apices the leaves are probably terete (Fig. 3D). However, in the middle part, even these thick leaves are flattened. The disposition of stomata in four zones, two on each pair of flanks, also agrees with the stomatal distribution in living bilaterally leaved conifers, though the zones are more diffuse than is common (see Florin 1931). The cuticle also shows wrinkling along the margins, supporting the idea that the leaf was thick (Figs. 5A, B). In some of the thickest cuticles, a few papillae on the epidermal cells can be seen (cf. Fig. 5D). These leaves with thick cuticle also show the largest lappets over the stomatal pit.

We only know one kind of pollen cone, and it has been already described (p. 107).

The seed cones are represented by four specimens, two with part and counterpart. To see the outside surface it is necessary to make a transfer of either part or counterpart. Some of these show the trifid bract, (Fig. 8H), and the whole surface of the bract is covered with cellular striae, but no veins can be made out. As already noted, the base of the cone scale was probably thick, perhaps terete, while Fig. 8F shows one cone in which the three lobes are not quite at the same level. Fig. 8G shows another cone scale, which indicates that the three lobes are all part of one structure, since they all spring from one common stalk. Two seeds is the normal number per lobe (Figs. 8F, G) but these may be of different sizes, there may rarely be only one, and, as already discussed, it is likely that only one or two seeds per unit came to maturity, rather as in *Dacrydium franklinii* Hook., where there may be ten or more seeds per cone, but only one or two ripen. Around the apex of each lobe there may be thickening rather like the ornament

FIG. 5.—*Rissikia media*, A, B; *R. apiculata*, C. D; *Elatocladus planus*, E.

A. Cuticle showing cells and stomata in irregular rows, with some wrinkling over the midrib (to left), x 400. Australian Museum AM 6409; B: cuticle near margin (to left) showing cells and stomata x 200, Australian Museum AM 6409; C. D: Cuticle showing stomata, possibly in single row on each flank, and margin (right and central). x 200, Australian Museum, AM 6405, 6406. E. imprint of (probably) epidermal cells and stomata x 100. University Tasmania.

put on the pastry round a pie. (Fig. 8F). The nature of this is unknown. On one cone scale (Fig. 8G) the lobes seem to be raised into a tongue-shaped flap of tissue pointing down over the seeds. The nature of this is unknown, though it is just possible that it might be the first sign of the enveloping epimatium (cf. Pl. 1J).

(c) *The type specimen and synonomy. Rissikia media* does not seem to be a common fossil. The original specimen consists of a single block (No. 102, Macleay Museum) showing parts of three shoots, the longest of which is designated as Holotype. The material is badly preserved, but of the right size, and as Tenison Woods (1883) observed the leaves show the impression of a pronounced ridge over the midrib. They are scarcely or not at all contracted at the base, and the apex is pointed, the tip being acute and symmetrically placed (Fig. 2A). The stem also shows the impression of pronounced angles, formed by decurrent leaf bases (cf. Fig. 39). Thus, in the available features, Tenison Woods' specimens agree with the better preserved ones, and is identified with them. His name has priority.

The original locality label reads merely "Ipswich" In Tenison Woods' day it was not fully realised that some of the rocks round Ipswich are Tertiary, unconformable on the Triassic coal measures, so some material labelled simply "Ipswich" is Triassic, and some Tertiary. The holotype of *R. media* is Triassic, for there is a specimen of *Dicroidium odontopteroides* on the block. Since the locality of the holotype is unknown, I suggest, that Burnera Waterfall is considered the *locus typicus*.

Voltzia cf. *liebiana* of du Toit (1927 p. 393, pl. 21, fig. 3) is another badly preserved specimen, from the Molteno. It shows no distinct differences from my material, and is probably identical with it. As Florin (1940) has clearly pointed out, the specimen is not a *Voltzia* and the specific name is wrong. This specimen, therefore, does not affect the nomenclature.

Carpentier's (1935) material from Madagascar is extremely interesting. His pl. 4, fig. 4, shows a complete shoot, with swollen base, that corresponds at every available point with *R. media*, and is therefore identified though we do not know its cuticle. The ascription to *Voltzia* was always uncertain. Carpentier's flora is almost certainly Lower Triassic, and this gives a range for *R. media* from Lower to Middle and possibly upper Triassic (see above p. 105). This is long, but not impossibly so.

Rissikia apiculata sp. nov.

Pl. 1C, D; 2D. Figs. 1 E-J; 3F; 4B, C; 5C, D; 6E, F, H, I; 7A, B; 8D; 9J; 10B; 14D, E.

Comparable specimens:

1935 *Phyllotheca* sp. Carpentier, pl. 5, fig. 2. Imperfect shoot, agreeing in general appearance.

Derivatio nominis: the pointed apices of the seed scale lobes.

Holotype: Australian Museum F; Pl. 2D. Locality as for *R. media*.

Diagnosis: Plant bearing foliar spurs 5-8 cms. long, spurs bearing twenty to forty leaves, rhombic in section, of more or less thick substance, about 5 mm. (4 mm.-10 mm.) long, not or only vaguely twisted into two rows up the shoot, and sometimes more or less appressed to shoot. Leaves about 5 mm. apart. Cuticle of leaf often thicker on one pair of flanks, showing cell outlines usually somewhat wavy, or else, if straight, very thin, (less than 1μ), outlines not pierced by holes. Stomata probably in 4 zones, each zone sometimes only one stoma wide, stomata separated by shared terminal encircling cell, or more than one terminal encircling cell. Guard cells only slightly sunken, surface about flat. Subsidiary cells bearing hollow cutin papillae, over-hanging, or not, the stomatal pit, sometimes only some subsidiary cells with papillae. Epidermal cells sometimes ornamented with solid cutin papillae.

Seed cone about 3 mms. long, probably with 12-15 units about 0.25 mm. apart. Bract about 1.5 mm. long and cone scale about 2.5 mm. Lobes of cone scale produced into a long point; the central lobe probably longer than the laterals. One seed only per lobe of cone scale. Seed about 0.5 mm. long at 0.25 mm. wide, more or less oval. Epidermal cells on bract, rectangular, about 30μ x 50μ; on cone scale cells elongated, about 40μ x 60μ; cell outlines thin, or minutely wavy, not pierced by holes, 0.5μ or less thick. Stomata not convex inwards, sometimes showing cutin papillae on subsidiary cells. Other epidermal cells very rarely papillate.

Description and discussion. (1) *General.* The leaves are always spirally inserted, but there is a good deal of variation in the way in which they are borne. Most commonly the leaves are borne all round the stem (Pl. 2D, Fig. 3F); however, in specimens with larger leaves there is a distinct tendency for the leaves to fall into two rows (Fig. 7B). It is interesting also that such shoots with larger leaves, in two rows, also tend to have slightly flattened leaves, in this grading into the normal situation in *R. media* (Fig. 7A). The correlation between larger leaves, borne in two rows and flattened has exceptions; Fig. 7B shows a specimen with long leaves, but (almost certainly) rhombic in section. The leaves are described as rhombic in section when they show a ridge down the (apparent) middle. The apices are generally pointed, and symmetrical (Fig. 4C).

The cuticle could only be prepared in small pieces, but certain of the larger fragmenst (e.g. Fig. 5D) show wrinkling both at the margins of the leaf, and down the middle. These wrinklings are (presumably) caused by compression, so their position supports the suggestion that the leaf was thick and rhombic in section. As in *R. media* the stomata are rather spread out, but there is the strong suggestion that they are in rows (Figs. 5C, D) apparently set in four zones, near to the margins, and thicker portion of the leaf over the midrib. However, in some of the smaller specimens each zone probably only consists of a single row of stomata, and their placing is not nearly so regular as in *Dacrydium elatum*, which has rather similar leaves. The cell outlines vary considerably. On the thinner cuticles they are straight, or nearly so, on the thicker cuticles, however, wavy (Figs. 6H), not because of cutin projection, but because the whole wall including the middle lamella is sinuous. Holes, such as are seen in *R. media* are very rare

FIG. 6.—*Rissikia media*, A-D, G; *R. apiculata*, E, F, H, I.

A, B, Stomata from the leaf, with surrounding cutin lappets, and subsidiary cells, Australian Museum, A.M. 6408, 6409; C. Stoma from the scale of a pollen cone, Australian Museum AM 6412; D: stoma from leaf, without ornament around it. Australian Museum F51962; E, F, H, stomata from leaf or seed cone (F), showing hollow cutin papillae around stomata pit, Australian Museum F51978, AM 6404, 6468. I: Stoma from leaf without surrounding ornament, Australian Museum F51976 all x 600.

indeed. Around the stomata, on the thicker cuticles, there are hollow papillae, often one per subsidiary cell. These are seen to be hollow because, unlike the lappets of *R. media*, a wall and lighter coloured, and therefore hollow interior can be made out (Figs. 6H). On the thinner cuticles the size and number of the papillae decreases, and some stomata show none (Fig. 6I). Papillae, but solid, also occur on the surface of the epidermal cells.

The female cone material consists of two incomplete specimens. One (Fig. 8D) shows a leafy stalk, on which the cone was terminal, fretted away at the base, indicating that the cone was not abscissed. The interpretation of the specimens depends much upon the interpretation placed on the *R. media* cone. The bract scale was certainly deeply lobed, and in Fig. 14D, a cone unit laterally compressed shows on one side two lobes to the bract scale, and on the other tissue which, from its level and position, is most likely a third lobe of the bract scale. As in *R. media* the cone scale consists of three lobes. In Fig. 14E they are seen adaxial surface towards the observer, and elsewhere, three stalks, joined below (Fig. 14D) which indicates that the three lobes, as in *R. media* were joined to one common axis below. So far as can be seen, the central lobe may have been larger than the two lateral ones. However, there seems to have been only one seed per lobe, though this observation is based upon only three units, two of which are shown in Pl. 1D and Fig. 14E. Some lobes, indeed show no sign of a seed, and it may be that sometimes there were less than 3 per unit. The lobes are only of moderately thick substance, and end in a long point (Fig. 14E, Pl. 1D). The seeds themselves, to judge from only two examples, were like those of *R. media*, though perhaps more elongated (see the imprint in Fig. 14E). One lobe, (Fig. 14D top right) shows the two ridged appearance already discussed, and interpreted as perhaps indicating the presence of two vascular strands.

The position and general appearance of the cuticles is as in *R. media* and again, for the most part, the cuticles are extremely thin. In one unit, however, the abaxial surface of a seed scale lobe was thicker than usual, and showed slightly sinuous cell outlines, and hollow papillae over three or four stomata. On the thin cuticles, however, only two stomata were seen; in them the guard cell surface appeared to be quite flat.

COMPARISON OF THE GENUS

(1) *Comparison of macrofossils.* No conifer comes very close to *Rissikia*, the following are moderately similar. *Voltzia* Bgt Florin (see Florin 1938-1935; 492-492, pl. 181/182). The young cone is not spike-like, but the cone does elongate as it grows older. The cone unit consists of a simple bract scale, and five scales, three associated with seeds, which form the cone scale. *Voltziopsis* Potonié (Florin 1944) has a cone unit showing a forked bract and five lobes to the cone scale, each bearing an inverted seed on the end of an adnate stalk. *Pseudovoltzia* Florin (Florin *loc. cit.* p. 479-484, pls. 179 and 180 and Schweitzer 1963). The cone is ellipsoidal in outline, and the cone unit consists of undivided bract scale, subtending an axis, produced into three lobes associate with two (or ? 3) inverted seeds, and two sterile lobes behind them.

Tricanolepis Roselt (1958) consists of three species *T. hoerensis* (Antevs), *T. frischmannii* and *T. monosperma*. In *T. monosperma* the seed cone is an elongated spike-like structure. The units in all species consist of a three pointed cone scale, borne on a somewhat elongated stalk, and divided for only about a quarter of its length. In all the bract appears to be adnate on to the cone scale. In *T. hoerensis* (e.g. Florin 1944, pl. 81-82, figs. 19, 20) and *T. frischmannii* there are three seeds, one per lobe of the cone scale, but in *T. monosperma* only one. Cuticular details are unavailable, though Roselt describes an embryo, so comparison with *Rissikia* is on general form only. And it is close. The chief difference is that in *Rissikia* the bract is free. Lesser differences are that the lobes of the cone scale are more deeply divided in *Rissikia*, though *T. hoerensis* comes close; and that in *R. media* all six seeds are borne at the same level, while the same is (probably) true of *R. apiculata*, whereas in *T. frischmanii* the seeds lie at different levels. However, in *T. hoerensis* the seeds lie at one level. Both genera display a trimerous arrangement of parts (or with reduction of the seed to one), a point discussed below.

I doubt whether any other of the fairly numerous fossil conifer cones is close enough to cause confusion, though several show one or two points of similarity, for example *Cheirolepidium muensteri* (Schenck) Takhtajan has peltate but not radially symmetrical scales on its pollen cone, like *Rissikia* (see Harris 1957) but is otherwise quite dissimilar. None of the foregoing genera have bilaterally flattened leaves. *Cycadocarpidium* Wieland has tripartite units to its seed cones, but the appearance of the parts is quite different (Frenguelli 1944c, Florin 1944).

The three Southern Permian conifers are also distinct; they show irregular branching, and the leaves and stomatal arrangements are also different (see Florin *loc. cit.* pls. 161-162 and 165-166 for *Buriadia* and *Paranocladus* and 1940 for *Walkomiella*) though the stomata of *Buriadia* and *Paranocladus* may resemble slightly those of *Rissikia*. *Walkomiella* also differs in its seed (see Surange and Prem Singh 1952).

Lebachia, and *Ernestiodendron*, the "walchias", though possibly foreshadowing the sort of structure shown by *Rissikia*, especially in branching pattern are distinct, at the generic level. The bilateral leaves of *R. media* separate it, at least from most Mesozoic conifers.

Genoites Feruglio (1942) looks at first much like the shoots of *Rissikia*, but may be distinguished by its leaves, which are divided into two over most of their length. Dr. S. Archangelsky tells me that this material is Permian not Liassic: with this age it looks similar to *Buriadia* Seward and Sahni.

(2) *Comparison of the pollen.* The striate disaccate pollens are very numerous and difficult. Somewhat arbitrarily, two groups are taken, very similar to *Rissikia*, and similar but distinguishable, and the large remainder, with which confusion is not very likely is ignored.

FIG. 7.—*Rissikia apiculata*, A, B; *R. media* C-E; *Dacrydium laxifolium*, F.

A, B: Parts of two shoots showing somewhat flattened leaves not much twisted into two rows (A), and thick leaves more or less strongly flattened into two rows (B) x 7. Australian Museum F51977, 51981, 40. C. Base of the cone, showing stalk and sterile units; D, E: Part of the cone showing scales from outside and seen laterally, and pollen sacs, all x 7, Australian Museum F51970, 51971 (cone). F: A cone unit showing two pollen sacs, and scale with tiny projection downwards, not attached to the pollen sacs. x 7. *P* = pollen sacs.

The very similar group consists of *Taeniaesporite krauselii* Leshik and also *T. noviaulensis* Leshik and a group of species centred about it. *T. krauselii* Leshik (1955 pl. 8, figs. 1-6) shows a rounder corpus than *Rissikia*, and fewer striae, but there is much overlap (Leshik fig. 2 and Fig. 9E, and Leshik fig. 3, and Fig. 9A), and I can see no character that separates the pollen grains satisfactorily. It might therefore be that one should use the specific name *krauselii* for *Rissikia media* but in ignorance of the plant producing *T. krauselii* pollen this would be unwise.

The grains centred about *T. noviaulensis* are difficult; they are taken here to be: *T. noviaulensis* (Leshik 1956, pl. 22, figs. 1 and 2); *T.* cf. *noviaulensis* Balme (1936, pl. 6, figs. 4-6): *T. novimundi* Jansonius (1962, pl. 13, figs. 19-25, except figs. 22 and 23: *T. interruptus* Jansonius (1962, pl. 13, figs. 26 and 27): *Striatites samoilovichi* Jansonius (1962 pl. 14, figs. 9-11): *S. samoilovich-pantii* Jansonius (1962 pl. 14, figs. 14 and 15: and *S. samoilovich-pantii* Jansonius) Klaus 1963, pl. 14, figs. 71-72): *T. ortisei* Klaus (1963, pl. 14, figs. 67-70): *T. labdacus* Klaus (pl. 13, figs. 65 and 66). In general these species differ from *Rissikia* in having sacii bulging beyond the corpus (polar views) and separated on the distal surface by a germination area more than half as wide as the whole corpus. Certain of them differ in number and sort of striae, or other ornament, but this is so variable in *Rissikia* that I place no reliance on it. The use of Schultze's mixture also introduces a variability that cannot easily be measured (Townrow 1962).

Another pair of rather similar grains is *Taeniaesporites alatus* Klaus (1963, pl. 13, figs. 62-62) and *Stratites marginalis* Klaus (1963, pl. 17, figs. 80 and 81). These two species differ from *Rissikia* in having (like *T. noviaulensis*) a wide germination area, and (unlike *T. noviaulensis*) sacci that do not bulge beyond the end of the corpus.

Certain of the species just discussed show the (possible) monolete mark, also rather rarely shown by *Rissikia*. Klaus (1963) was the first to give attention to this structure, and, for the present I do not utilise it as a character of taxonomic value (see p. 107).

The grains mentioned above are so similar to one another, and to *Rissikia*, that, with Balme (1963: 37), I think it likely that they form a "natural group" whether genus or group of genera one cannot say. For example, to take an argument by analogy, the pollen of four species of *Pteruchus* Thomas (see Townrow 1962a) and *Pteroma* Harris (1964) all placed in the Corystospermaceae, show a similar range of variation. So does the pollen of very similar group of species forming the sub section D. of Eupodocarpus (Gray 1956). These grains are non striate. *Arberiella* Pant (see below) has two species but there are not clear analogies to argue from among striate pollen. However the range of variation in *Rissikia* ties together the isolated grains just compared with it, into one group. If indeed these pollens form a natural group, its range is Upper Permian to Upper Triassic in the Northern Hemisphere, and perhaps basal Triassic into the Jurassic in the Gondwana region (Balme 1963).

The group of similar but distinguishable grains falls into several smaller groups; these are (as here taken):

(*a*) *Taeniaesporites albertae, T. gracilis, T. hexagonalis* and *Striatites rugosus* all of Jansonius (1962), with *Luekisporites multistriatus* Balme and Hennelly (1955, pl. 2, figs. 16-20), form a closely allied group, differing from *Rissikia* in having a corpus up to half as wide again as deep, instead of more or less round, and sometimes bluntly angled. As in *T. noviaulensis* the germination area is more than half as wide as the corpus.

(*b*) *Taeniasporites transversundatus* Jansonius (1962), *Striatites nubilus* Leshik (1956, pl. 21, fig. 14, also Jansonius 1962 pl. 14, fig. 20), *T. obex* Balme (1963) and *Luekisporites cancellatus* Balme and Hennelly (1955, pl. 12, figs. 11-15) differ from *Rissikia* in having a small round corpus, overlapped in the *Platysaccus* Naumova manner, by the sacci. *L. cancellatus* looks colpate in the figures, the rest are leptomatous.

(*c*) *Strotersporites richeri* Klaus (1963, pl. 15, fig. 76-66), *S. jansonii* Klaus (1963, pl. 15, fig. 74 and pl. 16, fig. 78) *S. wilsoni* Klaus (1963, pl. 16, fig. 77) with *Striatites jacobii* Jansonius (1962, pl. 14, figs. 16 and 17, Klaus 1963, pl. 16, fig. 79). *Taeniaesporites antinquus* Leshik (1956, pl. 22, figs. 4 and 5), *T.* cf. *antiquus* Balme (1963, pl. 16, fig. 13), and *Striatites dussenii* Jansonius (1962, pl. 14, fig. 13 only), form a group differing from *Rissikia* in being about twice as large.

Those referred by Klaus (1963) to *Strotersporites* Wilson show a monolete mark of the sort already mentioned, but while in *Rissikia* this mark (where present) is about a quarter as long as the corpus is wide, in Klaus' grains it traverses about the whole corpus.

It is beyond the scope of this note to discuss the extremely difficult and complex taxonomy of triate pollens, a subject discussed at length by Samoilovitch (1953), Makjavkina (1953), Potonie (1958), (Wilson (1962), Jansonius (1962), and Hart (1964, 1965). Now that some striate grains are ascribed to a parent plant, some points arise however.

It is now known that *Arberiella* Pant (possibly a glossopterid), and the conifer *Rissikia media* had striate grains. It is therefore clear that the habit arose at least twice, independently.

When one considers *all* available charactrs, striae, siz, corpus and saccus shape, and germination area, the two sorts of striate grain known to belong to different plants, are fairly easily distinguishable. However, the grains whose parent organ is known (both striate and non striate) suggest that efforts to draw generic boundaries using only some features, e.g. striae are ill-founded. Thus grains from one pollen sac of *Rissikia media* would fall into both *Striatites* Pant and *Taeniaesporites* Leshik as e.g. Jansonius (1962) defines those genera. If my earlier assessment is correct, one species of *Arberiella* was striate, the other was not (Townrow 1962).

Examination of grains much like *Striatites sewardii* (Virkki) Pant, now *Protohaploxypinus* Hart (1964), suggest that it is colpate. Virkki's (1937) fig. 2A and 3A shows, I believe, a colpate grain presented

FIG. 8.—*Dacrydium franklinii*, A; *Rissikia media*, B, C, E-J; *R. apiculata*, D.

A, A pollen cone, showing sterile units at base (to left and right). x 7. B, Base of pollen cone, stalk with remains of leaves, and sterile units at cone base x 10. Australian Museum F51970 51971; C, D, E: Seed cones, showing parts of the leafy stalks on which the cone is terminal. All x 3, F, Apex of a cone, unit seen face on to observer. G: Cone unit, face on to observer; H: Part of a cone unit, seen from abaxial side, showing bract and part of unit in lateral view; I. Cone units seen in lateral view, wrapping round cone axis (left) and in abaxial view, showing two ridges (left). J, lower part of a cone, and leaves on cone branch, all x 7. C, G. H, Australian Museum F51974: E, F, J, I, Australian Museum F51975: D. Australian Museum F51983.

in a somewhat rotated proximal polar view (not a lateral longitudinal view as Potonie's (1958) copy might suggest). Pl. 1I and Fig. 10E show a closely similar grain in similar views. Hart (*loc. cit.*) has utilised this feature, though probably misinterpreting it as a keel, but it may be of wider use when looked for.

Finally, to compare *Rissikia* pollen at the specific level, one has to combine several species into groups, (above), and I imagine that, if isolated, the grains of *Rissikia* would be disposed in four to eight species. There seems to be little object in making the species limits as narrow in isolated grains as seems to be usual. Balme (1963) who took a wider view of a species, is, I think, more likely to be right, (cf. the grains of *Pteruchus* and *Caytonanthus* (Harris, 1964, Townrow, 1962).

DISCUSSION OF THE GENUS

(1) *Ascription of the organs at the specific level.* Since both species are known in fair number only from the Waterfall locality, ascription of cones to foliage rests on anatomical resemblances only, i.e. upon rather minute and sometimes variable features. Also the cuticles of the cones are usually thin, and as already noted, when thin, even the leaf cuticles become difficult if not impossible to separate. The most widespread character is the nature of the cell outlines. In all organs named *R. media* the cell outlines are not sinuous, but are pierced with holes (though these may be few) and tend to be thick and of slightly indefinite margin. The cone named *R. apiculata* shows, at least sometimes, sinuous cell outlines, the outlines are not pierced with holes, and are very thin but of definite margin (Fig. 10B). This sort of difference has less taxonomic value than those based on stomata, but it can be used to separate, for example, the two species of *Microstrobos* Garden and Johnston. However, as noted, a few stomata of *R. apiculata* cone do show the hollow papillae characteristic of the leaf. This tends to tie that leaf and cone together; by elimination, the other sort of cone belongs with the *R. media* foliage. This generalisation is based upon less than 12 stomata all told on both cones.

(2) *Shoots similar to Rissikia, and comparison of the whole group of shoots.* From rocks of Jurassic and Triassic age there are other shoots, closely similar to *Rissikia*, the whole forming a somewhat easily recognised assemblage.

They are—

(*a*) unbranched, possibly deciduous, short shoots; i.e. a long shoot/short shoot system;

(*b*) long (1-8 cms.) narrow (0.25-2 mm.) bilateral leaves, more or less strongly flattened into one plane;

(*c*) the base of the shoot either leafless, or showing some leaves rhomboidal in section passing into bilaterally flattened leaves. (*R. apiculata* flattening slight or none);

(*d*) stomata, where known, disposed in four wide rows, and about equally numerous all over the leaf;

(*e*) stomata monocyclic, subsidiary cells few, not touching in adjacent stomata.

At the specific level separating the shoots is difficult, largely because microscopic detail is unavailable for many specimens. For the present, it will probably be best to define the species rather widely, frankly recognising that this procedure is unsatisfactory, but inevitable. On this basis, two species can be usefully separated.

Elatocladus planus (Feistmantel) Seward

Figs. 2C, D; 3C; 4E.

Selected references:—

1879 *Taxites planus* Feistmantel, p. 31, pl. 13, figs. 1, 2-8. pl. 14, figs. 1-5, pl. 15, fig. 2. Good Indian Jurassic material.

1882 *Taxites planus* Feistmantel, pp. 48-49, pl. 2, figs. 7-11. Upper Jurassic.

1902 *Palissya gracilis* Shirley, p. 8, pl. 2. From Stanwell, Queensland. Jurassic or Cretaceous: see Hill and Denmead 1960, p. 333.

?1913 *Elatocladus* sp. Halle, pl. 9, fig. 7, Hope Bay, Antarctica, Jurassic.

1917 *Taxites planus* Feistmantel, Walkom, p. 25-26, pl. 9, fig. 4. From Stanwell, (correlated with Walloon, but species has not been recorded in the Walloon of the type area).

?1917 *Elatrocladus* sp. Arber, pl. 13, fig. 9; Waikawa, New Zealand, Jurassic.

1918 *Elatocladus plana* Feistmantel, Seward, p. 432, fig. 802. Change of name.

1919 *Cycadites* sp. Walkom, p. 187-188, pl. 7, fig. 5. Part of leaf, Bexhill near Lismore, Jurassic.

1921 *Elatocladus planus* Feistmantel: Walkom, p. 14-15, pls. 4, figs. 1-4, pl. 5, figs. 1-3. From Talbragar, New South Wales, locality dated as lower Jurassic on its fish fauna.

1928 *Elatocladus planus* Feistmantel: Sahni, pp. 11-12, pl. 1, fig. 9, Good leaf base.

1928 *Elatocladus tenerrima* Feistmantel pars. Sahni. p. 11. Revision of Indian material.

1940 *Elatocladus planus* Feistmantel: Florin, pp. 43, 51-53, 59-66. Extended discussion, no new material.

Indeterminable, probably distinct.

1919 *Elatocladus planus Walkom*, ?non Feistmantel, pp. 43-44, pl. 2, figs. 4, 5. Lower Cretaceous, Burram, Queensland. Fragments showing probably bifacial not bilateral leaves.

Holotype: Feistmantel 1879, pl. 13, figs. 1, 1a.

Locus typicus: Venaravum, near Madras.

Description and Discussion. Material examined comes from Talbragar, Bexhill near Lismore and Bugaldie in New South Wales (where the shoot appears to be widespread), also there is a shoot from Stanwell, Queensland, and two from the Rajmahal Hills, India. This material is in the collection of the Australian Museum.

The foliar spurs are large, 8-15 cms. long, and show numerous leaves, which are generally close set, sometimes so that their margins touch, and like most of the group, the leaves are strongly

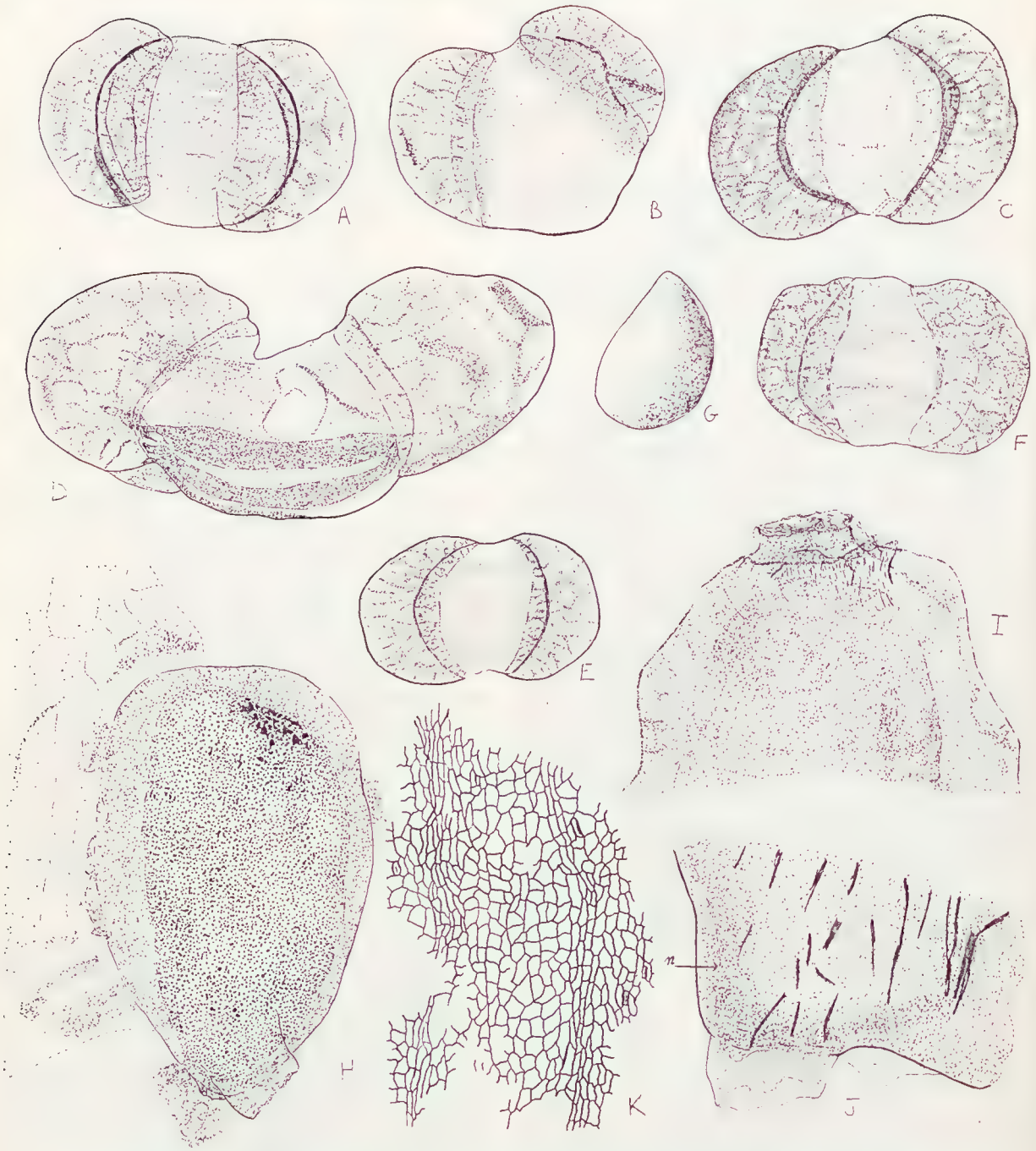

FIG. 9.—*Rissikia media*, A-E, H, I, K; *R. apiculata*, J, cf. *Luekisporites multistriatus* of Balme and Hennelly (1955), *F; Mataia podocarpoides* G. A, C, E: Pollen grains in polar view, with many striae (A), with none but a small crack or (?) monolete mark (C), or with few striae (E). B, D, grains in lateral longitudinal view, showing intact cappula, and variation in striae. F: Grain in proximal polar view, all x 600, except D, x 1,000. Australian Museum AM 6412: F Liveringa Frm. W. Australia, prep. Dr. B. E. Balme. G. A seed, similar to the seeds found in the cone, x 10 Canterbury Mus. 2517. H: A seed, partially macerated, showing seed stalk (curving to lower right), behind it micropylar regions and ? pollen. x 50. Australian Museum, F51974. I: Micropylar region of a seed, showing broken end of seed stalk covering integument and supposed nucellar projection x 70, Australian Museum, AM 6408. J: As I, showing line *n* believed to represent the edge of the nucellus, free from integument (heavy lines = cracks). x 70 Australian Museum F 51983. K: Cuticle from abaxial surface of seed scale complex showing lines of elongated cells (? over veins) and stomata. x 100. Australian Museum AM 6408.

flattened in one plane. The leaves are bilaterally flattened, and show parallel margins, tapering only at the extreme end, and uncontracted at the base (see Walkom 1925, pl. 4, figs. 2 and 4, and Figs. 3C, 4E, Walkom's pl. 4, fig. 2 appears to be mounted upside down). The apex is pointed, the apiculus being set more or less symmetrically (Fig. 3C).

In most figures and some material (e.g. Talbragar) the leaf looks flat and of thin substance, but other shoots otherwise similar show a strongly projecting midrib (e.g. from Bexhill). In one or two specimens from Talbragar, e.g. that shown in Fig. 2C, the plant material has been replaced by some siliceous mineral, giving, with the impression, the contour of the leaf. The leaf appears to have been strongly flattened, but substantial, and to have shown a distinctly projecting, but narrow midrib.

For the most part the replacing mineral shows rows of more or less equidimensional honey-comb like "cells" whose shape may have nothing to do with the cells of the plant, but in a few places, the outermost surface of the mineral shows a different pattern, elongated prints of cells, certain of which are set in an arrangement interpreted as the imprints of stomata (Pl. 2E, Fig. 5E). On this evidence, the stomata lay in two wide vaguely defined zones, and were well separated within these zones. The stomata are monocyclic and seem to show four subsidiary cells, as a general rule, but this sort of detail is extremely difficult to make out.

On one specimen (F. 38830, 38831, Australian Museum) there are two indistinct objects that might be parts of the seed cone, but they, like the various objects figured by Walkom (1921a), are too obscure to yield definite information about their nature.

The information is not enough to delimit the species satisfactorily and in fact it almost certainly will prove to be composite. The figured Indian specimens, and those from Stanwell, seem to show a smaller shoot with narrower leaves than the shoots from Talbragar. However, without more material and microscopic detail, I think an attempt to divide up the species would be premature.

As here understood, *E. planus* appears at the base of the Jurassic (Talbragar), and extends into the Upper Jurassic (Jabalpur series), being found in India, Australia, and probably New Zealand and Antarctica. Walkom's (1919) record from the Burrum (Lower Cretaceous) is probably distinct, but indeterminable.

E. planus can be separated from *Rissikia media* because it is a larger shoot, has flatter and (often) closer set leaves, and also on its base, which shows only few (2-4) leaves rhomboidal in section (Fig. 2C). There is, however, a good deal of overlap.

Elatocladus australis Frenguelli

Figs. 2E, 3B.

1944 *Elatocladus australis* Frenguelli, pp. 300-303, pl. 1, figs. 1-3. Holotype: Frenguelli *loc. cit.* pl. fig. 1.

Locus typicus: Cerro Bayo de Potrerillos, Mendoza, Argentine.

Description and Discussion. The only material I have seen consists of F. 50190-50193 in the Australian museum, originally from the Geological Survey of New South Wales. There is no information on the locality of the specimens.

The shoot is small (about 4 cms.) and shows rather well separated short (1 cm. or less) leaves. The leaves are bilaterally flattened, and strongly contracted at the base (Fig. 3B). The margins are not parallel, but bulge out slightly, a feature well seen in Frenguelli's material. The apex is obtuse, but shows a small, often curved apiculus, set usually a little nearer the basiscopic edge of the leaf (Fig. 3B and see Frenguelli pl., fig. 2, leaves 6, 8, and 9 on right).

Frenguelli's specimens have some plant material left, and in the figures the leaves look strongly flattened. In my material there is no plant material but the impression shows, much as in *E. planus*, a substantial but flat leaf, with a narrow distinct ridge over the midrib (Fig. 3B). The iron-stained impression shows the honeycomb-like pattern of the replacing mineral of *E. planus*, and also, but much more obscurely, the prints of epidermal cells and possibly, stomata, much as in *E. planus*.

The identification of my material with Frenguelli's is not certain, but the shoots agree in available features, and differ from the others of the group in the same way. These differences are definite enough, I think, to make it desirable to recognise a species, and they are: from *R. apiculata*, which in leaf size and spacing *E. australis* resembles, the leaves are flattened; and from *R. media* and *E. planus*, the shoot is smaller, (but there is overlap), the leaf base contracted, the leaf margins not parallel, and the apex obtuse, but with the apiculus not symmetrically set (compare Figs. 2E, 3A). Bonetti (1963, p. 38) compares *E. australis* with *E. conferta* (here renamed *Mataia podocarpoides* (Ett.)), but to judge from the figures the two shoots differ widely, for *E. australis* has bilateral leaves, but *M. podocarpoides* bifacial ones.

As noted in the preceding section, the two species of *Rissikia* and the two of *Elatocladus* considered are closely similar. I hesitate, however, to place them all in *Rissikia* until the cuticular detail of the *Elatocladus* species is properly understood. Probably, however, when more fully known, these four species will be disposed in one genus.

Table I sets out a comparison between the four species. As between the cuticles of the two *Rissikia* species the most constant difference, but not the easiest, is in the presence or not of holes through the cell outlines. An easier distinction, where present, is between solid or hollow papillae on the subsidiary cells. Thin cuticles, however, whether of cone or leaf, are scarcely distinguishable.

There are other supposedly bilaterally leaved conifers, but of Jurassic age, and these are comparable with *Rissikia*. They are *Elatocladus heterophylla* Halle (1913) and *E. tennerrima* of Sahni (1928). *E. tennerrima* (and *E. heterophylla*) is a branched shoot system, like an older shoot of *Podocarpus dacrydoides* (Fig. 2H), without clear separation into long and short shoots, and the stomata, though present all over the leaf, are much more abundant on one pair of flanks, and they are close set in rather regular rows (Sahni 1928, Florin 1940). *Retinsporites indica* Holden is extremely close to *Acmopyle* (see Florin 1940), and confusion with *Rissikia* is unlikely.

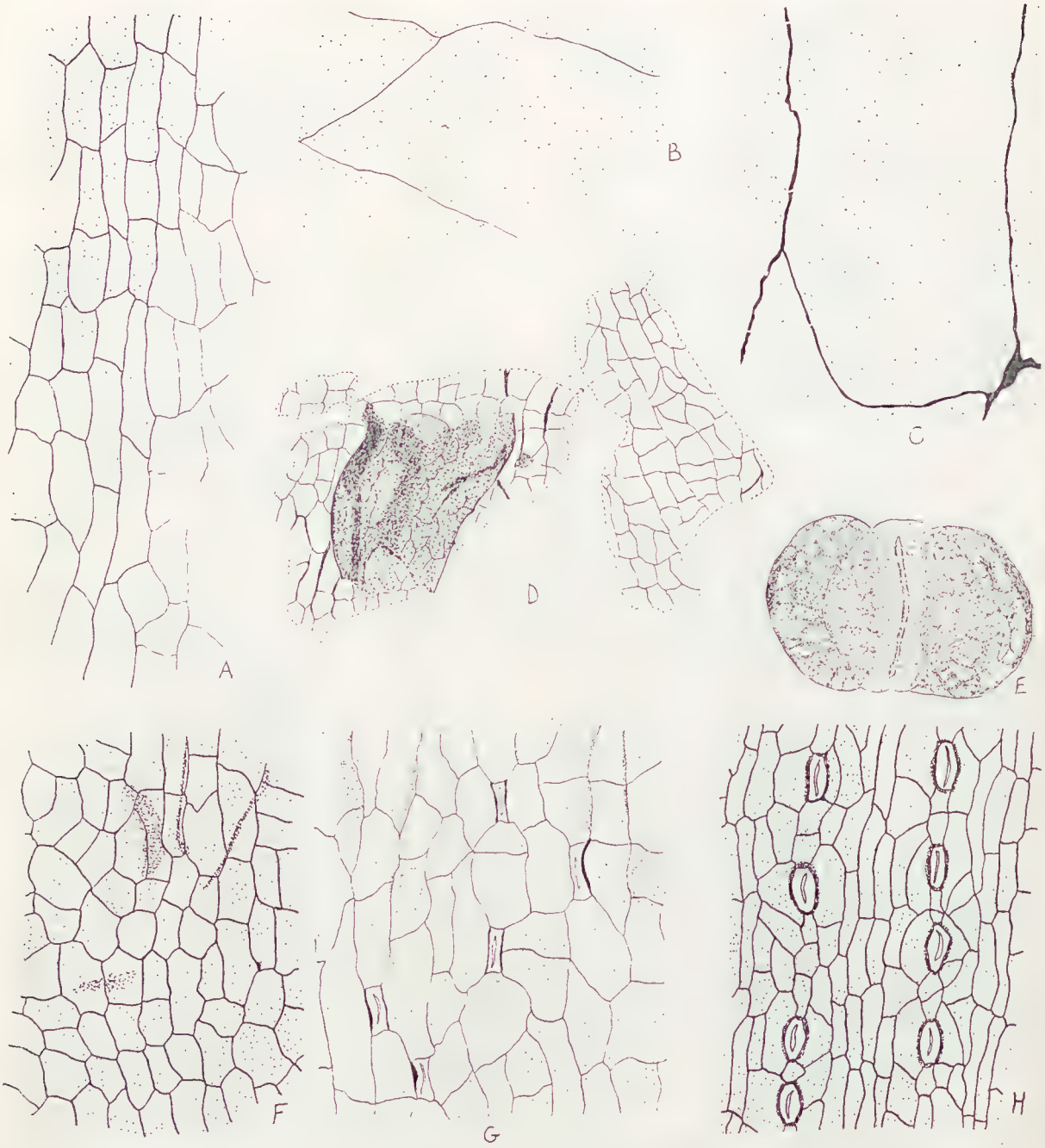

FIG. 10.—*Rissikia media*. A, C, D, F; *R. apiculata*, B; *Striatites sewardii* of Pant, E: *Metasequoia glyptostroboides*, G: *Podocarpus imbricatus*, H. A: Cuticle from cone scale, lower surface to left. x 200. Australian Museum AM 6408; B. C: Cells from seed cone showing slight difference in form of the cell outlines x 1000, Australian Museum AM 6407, 6408; D: Adaxial surface of cone scale, showing cuticle, and tube of cutin (seed stalk) lying over cutin but shown to be separate by large spore between tube and cutin. x 100 Australian Museum AM 6408; E: Grain in proximal polar view x 500, Liveringa Frm. W. Australia. Prep. Dr. B. E. Balme; F: epidermal cells from outward surface of cone unit x 100, Australian Museum AM 6412; G, H: Cuticle of species shedding leaves annually (G) or at a longer interval (H) x 200.

TABLE

SPECIES OF *RISSIKIA* AND *ELATOCLADUS* COMPARED.

	Shoot	*Leaf*	*Leaf Cuticle*	*Seed Scales*	*Cone Cuticles*
RISSIKIA MEDIA	Shoot about 7 cms. long (3-12 cms.)	Leaf thick but bilaterally flattened, margins parallel, not contracted at the base, apex symmetrical. Leaves about 3 mm. apart, 1 cm. long, and 2 mm. wide.	Outlines straight with holes, stomata with solid cutin lappets. Epidermal cells smooth.	Lobes obtusely pointed, sometimes dentate with two seeds per lobe. Lobes all about same size.	Cells—equidimensional on seed scale; stomata without cutin ornament. (Otherwise as per leaf).
RISSIKIA APICULATA	Shoot about 7 cms. long (3-16 cms.)	Leaves rhomboidal in T.S., margins parallel, not contracted at base, apex symmetrical. Leaves 3-5 mm. or less apart, 0.5 cm. long, and 1 mm. wide.	Outlines sinuous or (rarely) straight without holes, stomata with hollow papillae. Epidermal cells with solid papillae sometimes.	Lobes sharply pointed, not dentate, one seed per lobe, and central lobe larger than lateral ones.	Cells more or less strongly elongated on seed scale. Few stomata with hollow papillae (otherwise as for leaf).
ELATOCLADUS PLANUS	Shoot about 12 cms. long (5-18 cms.)	Leaves thick, but strongly flattened, margins parallel, not contracted at the base, apex symmetrical. Leaves 2 mm. or less apart, 2 cms. or more long, 204 mm. wide.	No information.	No information.	No information.
ELATOCLADUS AUSTRALIS	Shoot about 4 cms. long (3-5 cms.)	Leaves thick but strongly flattened, margins not quite parallel, leaf contracted at base, apex not symmetrical. Leaves about 3 mm. apart, 1 cm. long, 2 mm. wide.	No information.	No information.	No information.

FIG. 11.—*Mataia podocarpoides*. A-D, F: portion of foliage showing branching all x 1. A, B-D Canterbury Museum z P 185, z P 231, C zP 189, C, E, Australian Museum F51956; F, University Queensland F50768, E, G, H Parts of shoots showing form of leaves, H from Malvern Hills, all x 7, Canterbury Museum G 2; F, 231; H, 15.

(3) *Taxonomic Position*: *Rissikia* shows several points of approach to the "Walchias", but the seed cone indicates that it is quite separate from them. Likewise it shows an approach, in the unit of the seed cone, to certain Mesozoic conifers, especially *Voltzia* (see above p. 115). However, there are even greater differences. It seems to me that *Voltzia*, or *Pseudovoltzia* (see Schweitzer, 1963) and *Rissikia* are at the same level or organisation (or evolution), and perhaps in the Palaeozoic shared a common ancestor, but they are too different to group in the same Family.

Among living conifers, *Metasequoia* and *Taxodium distinchum* (L.) Rich in the Taxodiaceae, *Pinus*, *Larix* Mill and *Cedrus* L. in the Pinaceae, and *Acmopyle*, with *Podocarpus* Sections Davrycarpus Endl. and perhaps *Polypodiopsis* Bert. in the Podocarpaceae, show an unmodified system of long and short shoots. As for the leaves, bilateral leaves are found today *only* in the Podocarpaceae where they are associated with a long shoot: and short shoot branching pattern in *Acmopyle* and Section Dacrycarpus. Leaves rhombic in section on short shoots are seen in the (un-named) podocarp represented by Bower 199 and Schodde 1204 (C.S.I.-R.O.). The very thin leaves with four stomatal zones each only one stoma wide can be seen in young *Dacrydium novoguineense* Gibbs. The stomatal details of *Rissikia*, as noted, recall *Saxegothea* Lindl. and *Microstrobos* especially; these genera fall in the Podocarpaceae. Comparison is possible with *Metasequoia*, however (Fig. 10G).

The male cone is interpreted as showing two pollen sacs, and disaccate pollen. These features are found with regularity in the Podocarpaceae and Pinaceae only. The corpus and saccus shape and ornamentation seem to me to come close to *Dacrydium*, e.g. *D. laxifolium* Hook f. Striae are not known in any living conifer. It is true that *Ullmannia* Goepp. among Mesozoic conifers has only two pollen sacs per unit (Florin 1944), but this conifer differs in so many other respects from *Rissikia* that I disregard this similarity.

A spike-like seed cone is seen in the podocarps *Dacrydium franklinii* with *Podocarpus spicatus* and *P. andinus* (Wilde 1945). Other families have cone-like cones, or reduced cones, as *Juniperus* L. Trifid scales in which the lateral points are small are seen in *Pseudotsuga* Carr. and *Larix* Mill. (Pinacea) but no podocarp clearly shows this feature. However, in *P. andinus* (judging from three trees in the Hobart Botanical Garden) in the larger flowers on a cone, the bract may show small lateral points, as well as the slightly pointed apex (Fig. 14F); and this feature can be interpreted as a much modified trifid structure.

The cone scale in *Rissikia* is basically 3 partite, each lobe possibly having a double vascular trace. *Dacrydium franklinii* shows a cone scale often (if not normally) produced into three points; *Michrocachrys* is similar (Fig. 14H), and so is *Saxegothea* The cone scale in all these is a small non vascular structure. In *P. spicatus*, and *P. andinus*, *two* vascular traces proceed past the chalaza into the further part of the epimatium (Sinnott 1913). It thus seems to me that these podocarps (also resembling *Rissikia* in having several seeds per cone, not one as is normal among podocarps) are explicable rather easily in terms of the *Rissikia* cone unit: *D. franklinii*, *Microcachrys*, and *Saxegothea* retaining all three lobes of the cone scale, though they are much reduced: while the double trace of *P. spicatus* epimatium recalls the (supposed) double trace in one lobe of the cone scale in *Rissikia*.

Another point is that *Rissikia* is linked to the living podocarps by *Mataia* (see below, p. 133), which falls nearly exactly halfway between *Rissikia* and *Podocarpus* sect. Stachycarpus or *Rissikia* and some *Dacrydium* species. Moreover, *Mataia* is also intermediate in age (p. 129).

Other conifer families show evidence for derivation from a complicated seed scale complex (Florin 1950 for summary), but none, it seems, is clearly characterised by a tripartite arrangement of parts in the seed scale complex. Rather, two, five or seven appear to be indicated, as well as one, through some genera (*Cunninghamia*, rarely *Athrotaxis*) seem to have a tripartite symmetry. If, as I think was the case, the nucellus of *Rissikia* projected beyond the integument, we have an unusual situation shared by *Saxegothea* alone (see Tison 1909 for example). However, in *Saxegothea* the nucellar projection is solid and acts like an Angiosperm stigma, whereas any nucellar projection in *Rissikia* may have been hollow.

Rissikia has more than one seed per unit, the Podocarpaceae one only. However, as seen on p. 115, there is reduction in the genus, *R. media* showing two per lobe, *R. apiculata* one only, and possibly also having some sterile lobes. There is also evidence that not every ovule reached maturity. The gap in this respect, is not very wide, it is again partly bridged by *Mataia*.

Taking all the above points into consideration, it seems to me that *Rissikia* falls with the Podocarpaceae, and with no other Family. The only Family that otherwise enters the picture is the Pinaceae, and this is very interesting, for others (e.g. Van Campo-Duplan (1950)) have suspected a connection between the Podocarpaceae and the Pinaceae.

For the present, I refer *Rissikia* to the Podocarpaceae, even though this does involve a slight widening of the limits of the Family (see Pilger and Melchior 1954, p. 357). Confusion is unlikely, for the modification needed is small. The alternative would be a new Family, and there seems no object in this.

Genus **MATAIA** nov.

Type species: *M. podocarpoides* (Ett.) see below..

Diagnosis. Woody conifer, showing main shoots bearing laterals in groups, possibly false whorls, at intervals. Leaves bifacial, small, 1.5 cms. long or less, borne spirally but twisted more or less distinctly into two rows. Shoot bases showing a few (about 6) small scale-like leaves, not twisted. Leaves more or less strongly concave, on the lower surface, with projecting midrib on lower surface, contracted at base, but not showing distinct petiole, leaf widening rather gradually; at apex leaf contracting abruptly to an often acute apex. Leaf margin same thickness on rest of leaf, not scarious. Leaf substance thin and fragile.

FIG 12.—*Mataia podocarpoides*. A: Cuticle (supposed under surface) and stomata x 400; B: Two layers of cuticle along leaf margin (heavy stipple) x 200; C: A stoma showing solid papillae round stomatal pit x 600, Canterbury Mus. ZF 15: D: Cuticle of under surface of the leaf x 200; E: stoma, 600, University of Queensland F50769.

Cuticle thin, about 1μ on (supposed) upper leaf surface, and slightly less on the other leaf surface, showing rectangular cells in more or less regular rows. Leaf either hypostomatic or very unequally amphistomatic; longitudinally orientated stomata lying in rows on one (presumably lower) leaf surface in two zones. Cell outlines slightly sinuous or pierced by small holes, or both, cuticle surface smooth. Stomata monocyclic, in often irregular rows, sometimes having touching subsidiary cells, or very rarely shared subsidiary cells, more usually stomata more distant from each other. Subsidiary cells 4-6 unspecialised. Stomatal pit rectangular, normally overhung with separate or somewhat concrescent papillae; continuous ring of thickened cutin round stomatal pit (Florin Ring) absent. Cell outlines sometimes appearing double.

Seed cone spike-like, about 3 cms. long, having a few leaves like the foliage leaves at its base, followed by a leafless portion up to 3 mm. long, and 8-12 well separated spirally arranged units. Each unit consisting of small, entire more or less triangular subtending bract and axillary cone scale. Cone scale consisting of thick (probably nearly round) stalk, expanding into an entire broadly hastate scale, of overall length about 3 mms., about half as wide as long, and showing apical third to quarter turned back over the adaxial scale surface. Two stalked seeds borne on adaxial surface of scale; seed stalks arising about at distal end of cone scale stalk, lying over, but (in all probability) free from scale margin. Seeds (or ovules) round in section, inverted, partly covered by overfolded portion of scale, about 1 mm. x 0.75 mm., free from the scale. Pollen cone and microscopic details of seed cone unknown.

DESCRIPTION AND DISCUSSION

(1) *Use of one name.* On the holotype, the base of the cone is probably seen (Fig. 13A). This shows a number of leaves, of shape much like (but not entirely like) the foliage leaves. The resemblance extends to their convex shape and projecting midrib, but cuticle is not available. This is a sort of organic connection, and is the chief ground for using one name for both foliage and cone.

There is also the evidence from association at one, just possibly two, localities. At the Clent Hills the only conifer known so far is *M. podocarpoides* (foliage): it is common, and has already been tentatively compared with *Podocarpus* (e.g. Florin 1940). The cone, also *Podocarpus*-like is found lying with shoots.

In the Malvern Hills, from which *M. podocarpoides* foliage is known, I have found seeds, in size and gross shape indistinguishable from those in the cone from the Clents but again lacking cuticle (Fig. 9G). However, there are two floras in the Malvern Hills, one with Angiosperms, and I am not certain which my small seeds belonged to.

The Clent Hills material is somewhat metamorphosed, and no cuticle is available. Essentially, however, the plants are finely preserved. Examined dry, the material often is disappointing, but when covered with kerosene (or better, xylol) a great deal of detail previously invisible comes to view.

(2) *General form.* In the material now called *M. podocarpoides* the branching is irregular. In some shoots (Figs. 9A, D) there appeared to be groups of side shoots, which may be false whorls, set at intervals; Bonetti's (1963) shoot shows this excellently. In the living *Podocarpus lawrencei* Hook f., as in some similar trees, the branching shows similar groups of laterals (Fig. 2F), but again as in *M. podocarpoides*, the laterals are not of limited growth, but themselves grow on to produce further groups of laterals of the second order. In the living species the groups of branches arise more or less annually, and where the annual increment is small (as in the mountain top habitat of *P. lawrencei*) the branching pattern becomes obscure. This sort of branching grades into the modified pinnate sort seen in *P. spicatus* but generally they are distinguishable.

The leaves of the New Zealand material available to me are not thick. They appear so, but when they are seen compressed lower surface downwards (as judged from comparison of part and counterpart), the fossilised leaf is seen to be strongly convex, the midrib being supported by the raised matrix of the impression beneath the leaf, (Figs. 11 E, G, H). On Walton's compression theory, this means that in life the leaf was thin and concave. The midrib projects downwards in the fossil, appearing as a trench on the impression.

The cuticle will be discussed in the specific description.

(3) *Seed cone.* The general outline of the cone is shown in Pl. 2G. The length of the leafless stalk is not known, in the most complete specimens it is 2 mms. long (in *P. spicatus* the stalk may be 1 cm. long, also without large leaves).

The evidence for the form of the base of the cone comes from the holotype. This specimen (probably collected by Haast) is not well preserved, and has lost much of its plant material, leaving one to judge the form of the organ from differences in level in the rock. The base of the cone swells into a little knob (like some shoots), and also like *Podocarpus andinus* in which the abortive cones are shed entire, and possibly the fossils represent abortive cones. On either side, there are three impressions, apparently attached spirally, interpreted in Fig. 12A as leaves, though they are obscure. The uppermost on each side, and the lowermost of the right hand side still have, however, some plant material, showing the midrib and what looks like a concave lower leaf surface. In showing leaves set a little way up the cone base, *M. podocarpoides* recalls the living *Podocarpus standlei* Bucholtz and Gray (1950), of section Stachycarpus.

The bract was seen complete (or nearly so) in three units only (Figs. 13 A, C, B), in all it was single and entire. The stalk of the cone scale appears about the same thickness whether compressed ventrally or laterally (Figs. 13C, D): it must therefore have been nearly round in section. Without a cuticle, it is not possible to be certain that the apex of the scale is turned over, but the circumstantial evidence is strong. On all the units there is a line of carbon (i.e. tissue) crossing over the chalazal end of the seed, and traceable back to the margin of the scale, (Figs. 13B, C, D), while in those units compressed dorsi-ventrally the same line can be seen, here often associated with a difference in rock level, coming to a point

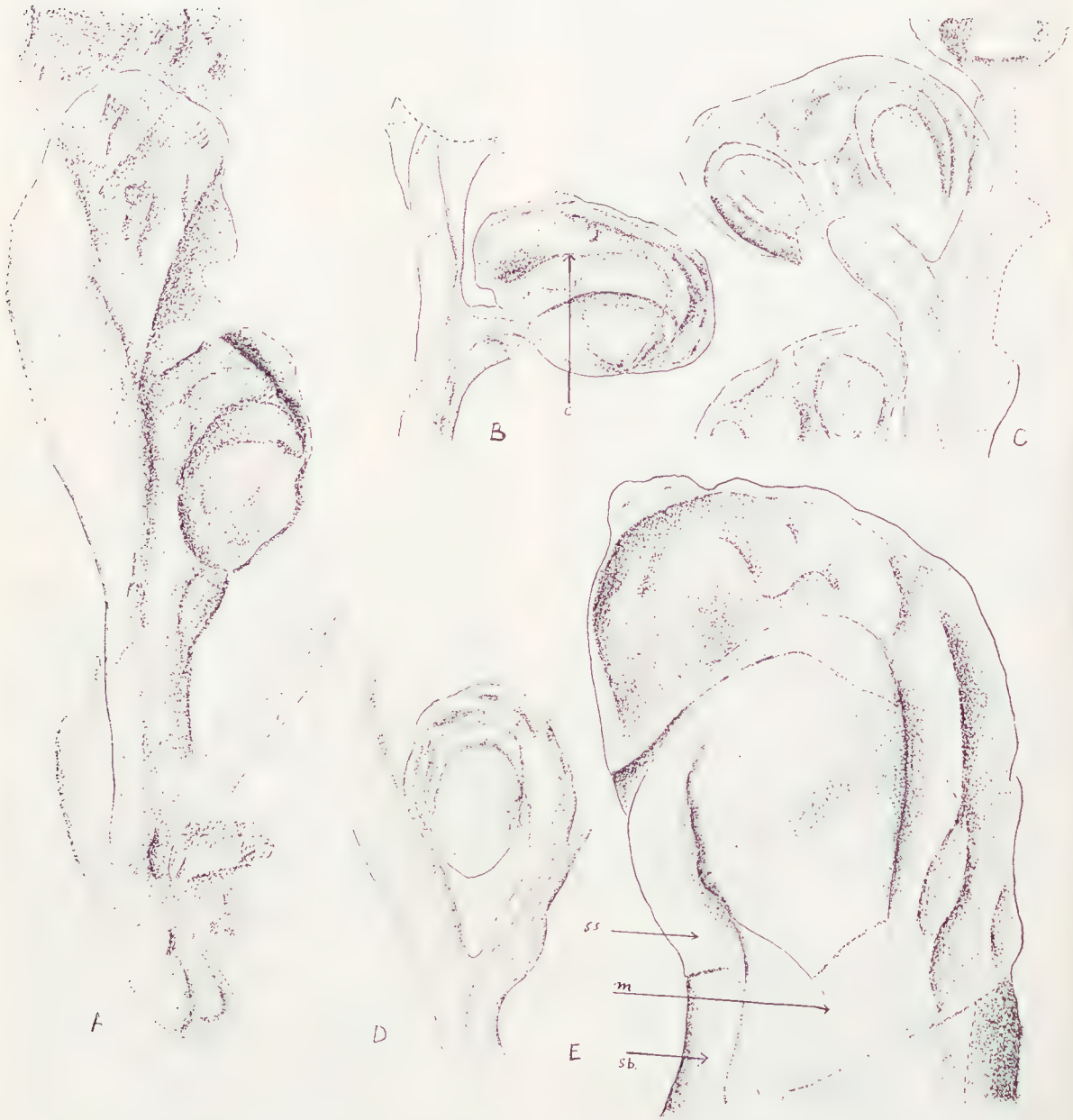

FIG. 13.—*Mataia podocarpoides*. A: Lower part of the holotype, base of cone, leaves at cone base, and two units, lower right compressed laterally, upper abaxial surface seen, note ridges on cone scale. x 7, Canterbury Museum z P 190; B: Flower (or cone unit) with only one seed, compressed laterally; C: Counterpart of unit shown in Plate 1 J, seeds and bract; D: Unit compressed laterally; E: Unit compressed partly laterally, partly dorsi-ventrally x 14, rest all x 7. New Zealand Geological Survey 581/519. *ss* = seed stalk, *sb* = position of seed stalk which is broken up off the seed scale, *m* = micropyle, *c* = edge of the unfolded part of the seed scale.

(Pl 1J). The other possible explanation, that the adaxial scale surface is raised in a lump, is very unlikely because the tissue is smoothly continuous over the overfolded portion (as it is here interpreted), on to the abaxial scale surface (Pl. 1J, Fig. 13G, D). Accepting the first view, the cone scale was a simple, bluntly pointed structure: to judge from the wrinkling in the fossil, it was probably also thick, As noted in the diagnosis the over-folded portion of the scale overlaps parts of the seeds, and may have been in contact with them, since mud is not found between seed and scale at this point.

In these cone units compressed more or less laterally, there is a bar of thick material running from the seed to the scale stalk (Figs. 13B, E). Towards its distal end this bar can be broken off the underlying plant material, and in one unit (shown in Fig. 13E) there is a layer of mud between it and the scale. This is interpreted as a seed stalk, which must have been free from the scale at least for part of its length. The stalk lies at the edge of the scale; it is not clear whether it was lateral or adaxial to the scale, but probably it was adaxial. It joins on to the distal end of the seed showing that the seed was inverted.

Nothing in the seeds can be made out except that since they are the same thickness however compressed, they must have been round in section. The narrow end (micropyle) shows no sign of a projecting nucellus.

The name is from Matai, Maori for *Podocarpus spicatus* R.Br.

Mataia podocarpoides (Ettinghausen) com. nov.

Pls. 1J, 2G; Figs. 9G, 10A-D, F, 11, 12, 13, 14A, 15C, D.

1891 *Palissya podapoides* Ettinghausen, p. 31. Nomen nudum. Material here re-examined.

1917 *Elatocladus conferta* Arber non Oldham and Morris, pp. 9 and 58-59; pl. 1, figs. 1-3; pl. 6, fig. 4; pl. 13, fig. 11 and pl. 8, fig. 6. Various New Zealand localities.

1963 *Elatocladus conferta* Bonetti non Oldham and Morris, pp. 37-39, pl. 7, figs. 1 and 3. Middle Jurassic, the Argentine.

Comparable material: *Palissya australis* McCoy (Sterling 1900, p. 6 pl. 3, figs. 8, 9).

Holotype: Fig. 13A, of No. Z.P. 190 Canterbury Museum; Ettinghausen's specimen.

Locus typicus: The Clent Hill, Jurassic (? Middle Jurassic).

Diagnosis emended: Sprays of foliage showing spirally inserted difacial leaves, twisted into two rows except at the leaf base. Spreading leaves 0.5-1.5 cms. long, strongly decurrent, leaf margin contracting somewhat gradually to decurrent base, apex usually acute, leaf 0.2-0.4 cms. wide. Leaf more or less concave, midrib usually distinct.

Cuticle 1μ or less thick, of different thickness on each side of the leaf. Cuticle of (presumed) upper surface showing rectangular cells, about 60μ x 30μ, with wide cell outlines appearing double; outlines up to 3μ thick, and these cells not usually pierced by holes. On lower cuticle, non stomatiferous margin at least 10 cells wide, stomatal zones containing 8-10 rows of stomata, cell sizes as for upper leaf surface. In zones cells about 40μ x 30μ, and cell outlines pierced. Stomatal pit, more or less rectangular, usually 5 subsidiary cells (one lateral divided); showing either one low solid papilla each, or terminal subsidiary cells lacking a papilla, or papillae more or less concrescent. Pit about 30μ x 10μ length of pore about 20μ.

Seed cone over 2 cms. long, leafless pedicel 0.25 cms. long (total length unknown). Bract about 2 mms. long, 1 mm. wide at the base, somewhat rounded. Scale about 4 cms. long, including overfolded portion 0.5-1 mm. long, and 2-4 mms. wide. Apex bluntly pointed, margin of scale entire. Seeds about 1.5 mm. long, 1.0 mm. in diameter, lying at an angle of about 60° to one another; seed stalks about 0.25 wide.

DESCRIPTION AND DISCUSSION

(1) *Form and general.* Most material comes from the Clent Hills, Canterbury, New Zealand, and was either in the collection of the Canterbury Museum, or was collected by Mr. G. Grindley and given to me, or (most) was collected by Mr. Allan Beck, New Zealand Geological Survey, and I. One specimen comes from the Malvern Hills (Fig. 9G) and one from Caledonia No. 5 Colliery near Walloon, Queensland (Fig. 11F).

Only the Malvern Hills and Caledonian specimens have cuticles. Both are, however, indistinguishable in gross form from the Clent Hills twigs. The Caledonian specimen, represents the first record, having form and microscopic detail of *M. podocarpoides* in Australia.

The branching and leaf form have already been discussed. There is a good deal of variation, even in one twig, in the leaf size and shape (Figs. 11 A-D): in general the smaller leaves tend to be wider in proportion to their length. Also, the apex may be merely acute, and may contract less sharply than is usual (Fig. 11E). However, these differences are, in the Clent Hills material at least, rather minute; all share the thin leaf substance, concave shape and narrow projecting midrib.

The cuticle is difficult to study and the interpretation given, though it appears to be the simplest, is not the only one possible. On maceration the material broke up into small rhombs, but these covered all parts of the leaf. The cuticle pieces fall into two groups, a thicker group entirely, without stomata, and a thinner group which showed all the stomata seen. This suggests that the leaf was hypostomatic, but it remains possible that it was very unequally amphistomatic, like *P. andinus*. The margin shows unmodified, but wrinkled cells (Fig. 12B), indicating that the margin was thick and not scarious. The stomata lie in rows and on the fragments are confined to strips of cuticle (Fig. 12A, D), indicating that they lay in zones. In the zones the rows are not entirely regular, rather as is *Podocarpus ferrugineus*, and they are not as closely packed as in, say, *Saxegothea* (Fig. 14B). A Florin ring could not be seen, but the stomata showed low solid papillae, like *Rissikia*, and these were sometimes concrescent. The sinuosities on the outlines are very small and often absent, and it is not possible to be certain that the middle lamella was sinuous or not; I think it

FIG. 14.—*Mataia podocarpoides* A; *Saxegothea conspicua* B, C; *Rissikia apiculata* D, E.

A, C: Cell outlines compared, showing apparently double appearance grading into outline with more deeply penetrating "middle lamella" region. x 1000, A, University Queensland F50769, B and C, Nat. Herb. Melb. Buchtien 1903. B: Lower cuticle with stomata x 400; D: Part of a seed cone, showing broken bases of three lobes of seed scale complex (lower left), three parts of bract, (b1, b2, b3), seed scale in abaxial view (top right) and tip of lobe of cone scale (bottom right) x 14; E: Part of seed cone, showing imprint and part of single seed associated with two of the three lobes of cone scale x 14. Australian Museum F51983.

sometimes was (Fig. 12C), so that the sinuosities compare with the small ones seen in *Podocarpus gnidioides* Carriere. The outlines are also occasionally pierced by small holes. In the thicker cuticle the cell outlines were wide, and the central part stained very feebly, giving the outline the appearance of being double. This appearance is only seen in the wider outlines, and there is a series from outlines with a clear central portion, to ones in which the central portion is quite absent (Figs. 12A, 14A). A slightly similar effect may be seen rather rarely in *Saxegothea* (Fig. 14C). Here the central portion is bordered, and penetrates some way down into the leaf. However, it sometimes does not stain very fully, and then the outline appears double. Presumably the fossil is similar. Incidentally, in *Saxegothea* the papillae round the stoma discussed by Florin (1931, see also Fig. 14B) are not always present.

The cones have split more or less through the middle, so that structures on the outside, such as bracts, are only seldom seen intact. The one in Fig. 13C was bared by dissecting away the rock and plant material over it. The scanty material cannot give a proper idea of the range of variation in the cone, but the number of seeds (or seeds reaching maturity) is variable. Mostly it is two, but in the uppermost and lowermost complete cone units it is only one (Fig. 13B). In one cone unit (Pl. 1J) one seed is compressed more or less exactly dorsi-ventrally, the second partly laterally. This means, I take it, that the rather wide scales were curved round the axis. On one unit, (Fig. 13A, the lower one) two ridges ascend the abaxial side of the seed scale complex. *Rissikia* showed a similar appearance and it was suspected there that the ridges contained veins (p. 109), possibly they do in *Mataia*.

(2) *Specific identities and comparison with Elatocladus conferta* Oldham and Morris *and E. jabalpurense* Feistmantel.

As with *Elatocladus* species resembling *Rissikia*, the species resembling *M. podocarpoides* are not well known, and a satisfactory scheme is impossible. Florin (1940) discussed these shoots at length, but my suggestions differ somewhat from his.

Elatocladus confertus Oldham and Morris (1862, pl. 32, fig. 10). See also Feistmantel 1877, pp. 85-86, pl. 45, figs. 4-8a; 1877a pp. 183-184, pl. 5, fig. 3, pl. 8, figs. 1-6; Halle 1913, pp. 86-87, pl. 8, figs. 26-40; Sahni 1928, pl. 1, figs. 4-8; consists of shoot systems showing a more or less pinnate habit of branching. This is not seen in Oldham and Morris' original figure (a fragment only), and in Halle's figure (1913, pl. 8, fig. 26) it is possible that the branching is not pinnate, but in most material it is plainly pinnate. The leaves are short (0.5-1.5 cms.), twisted into two rows, and, where well seen (e.g. Halle 1913, pl. 8, fig. 32 or Feistmantel 1887, pl. 45, figs. 9, 9a,) contract more or less sharply at the base to a distinct petiole (not always seen, e.g. Feistmantel 1877, pl. 45, fig. 8a). On the other hand the leaf apex contracts only rather gradually to a more or less sharp apex. The leaves are said to be thick, but I doubt this, they might be concave. *Elatocladus jabalpurensis*. Feistmantel (1877a, p. 16, pl. 9, pl. 10, fig. 1: 1879, pl. 12, fig. 4: Sahni 1928, pl. 5, figs. 71-75), consists of pinnately branched shoots, with leaves about 1.5-2.5 cms. long twisted into two rows, and contracted rapidly to a distinct petiole. The apex tapers slowly to an acute tip but over most of the length of the leaf the margins are parallel. I do not know whether the leaf is concave or not. Sahni (1928) describes a cone associated with the foliage. No detail is available, but the general form of this cone, is similar to *Mataia* (see pl. 5, fig. 72, extreme right, and others). It is not placed in *Mataia* because I have not examined material and the details are not clear, but from the figures it appears to have only one large seed per cone unit, and so to come closer to *Podocarpus* Section Stachycarpus than *Mataia*. Arber's (1917) specimens and mine do not show pinnate branching (see also Bonetti 1963) though their branching pattern grades into that of *E. confertus* and, at least in most shoots, the leaf shape differs. From *E. jabalpurensis*, *M. podocarpoides* differs in leaf shape. Two records, *E. confertus* of Edwards (1934) and *E. jabalpurensis* of Sahni (1928, p. 12; *E. conferta* of Feistmentel 1882 pl. 2, figs. 10, 10a) show bilaterally flattened leaves, and so differ from any of the other specimens discussed here.

These differences between *M. podocarpoides*, E. *confertus* and *E. jabalpurensis* are admittedly small, but they do enable the material to be split up. A new name is needed for the New Zealand material, and Ettinghausen's (1881) *Palissya podocarpoides*, originally published without figure, is revived and his specimen figured, as the holotype. I express no opinion as to whether the three species discussed are as closely related as Florin (1940) suggested.

DISCUSSION OF THE GENUS

(1) *Generic comparisons*. The spike-like cone of *Mataia*, and the construction of the individual units, as here interpreted, probably remove it from close comparison with any known fossil conifer. *Callipitys Harris* (1935: 110-111) might perhaps be confused, but it differs in having no separate bract (i.e. the cone scale is simple, see p. 111), and in the orientation of the seeds (ovules) which are directed upwards and unstalked, whereas in *Mataia* the seeds are inverted and stalked (it is admitted that cuticle is needed to prove both statements about *Mataia*).

Among living Families the Podocarpaceae seems to me to be the only one in view. Superficially the cone recalls the cone of *P. spicatus* or *P. andinus*, but differs from these, indeed any living podocarp, in often or usually having two seeds per cone unit. The form of the scale removes *Mataia* from any living podocarp genus, though in *Microcachrys* and also *Saxegothea* (Figs. 15H), whose cones are otherwise quite different, the seed scale folds over the seed in a similar way.

However, though different from any extant genus, I place *Mataia* in the Podocarpaceae, primarily on the form of the seed cone. The difficulty about there being more seeds than just one per cone unit, I do not think is important, in some units of the present material there is only one seed. The foliage offers confirmatory evidence. In gross form and cuticle (so far as known) it is much like *Podocarpus*.

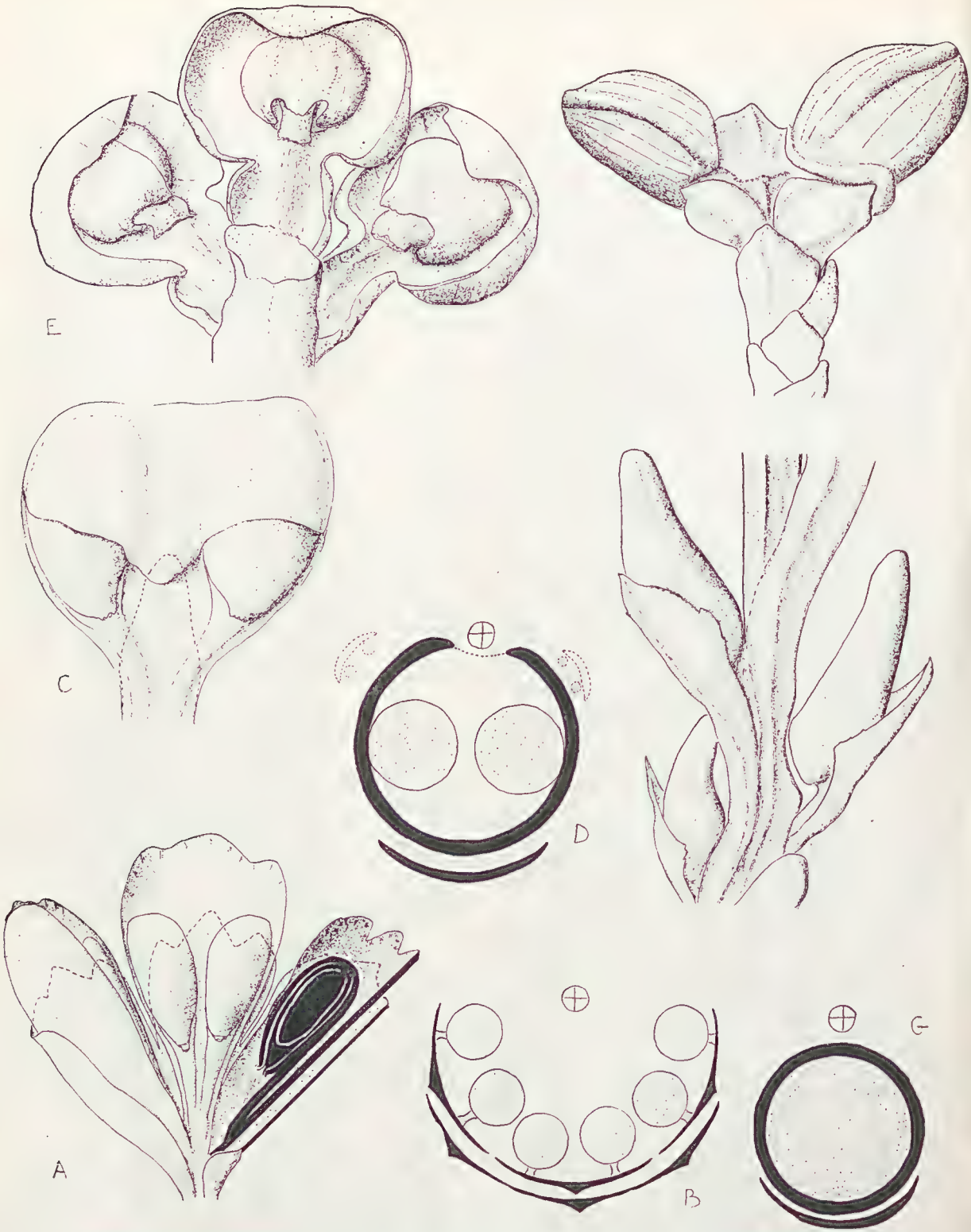

FIG. 15.—*Rissikia media* (reconstruction), A, B: *Mataia podocarpoides* (reconstruction), C. D; *Podocarpus andinus*, E, G; *Dacrydium bidwillii*, F; *Microcachrys tetragona*, H.

A: Reconstruction of a cone unit, seen abaxial surface facing observer, bract dotted, cut tissue solid black, x ca. 10; B: Floral diagram (Florin's terminology) of one cone unit; C: Reconstruction of cone unit, as A, x ca. 10; D: Floral diagram. E, F. H The cone, or parts of the cone, showing (E, F) two sorts of epimatial seed, and H, three of a whorl of four, showing large bract, and three-pointed seed scale, all x 7. G. floral diagram of E.

NOTE.—

(i) The seeds are stippled in B, D and G; parts missing as between B and D, dotted in D.

(ii) The diagrams are drawn as the units are, i.e. as dorsiventrally flattened. These diagrams are therefore not entirely comparable with those of Florin (1944), which interpret several conifer flowers in their supposed primitive radially symmetrical form.

There is uncertainty as to which section or genus *Mataia* resembles most. In *Podocarpus* Section Stachycarpus the branching may be more or less pinnate, but the laterals are not of limited growth, nor very numerous, so that the distinction between the main (penultimate) and side (ultimate) shoots is blurred. In Section Eupodocarpus Sub-sect. D. (Gray 1956) the branching is not strictly pinnate (Fig. 2F) but as in *Mataia*. In leaf shape, a concave leaf is found widely in Section Stachycarpus (e.g. *P. spicatus, P. ferrugineus* and *P. andinus*), but though it does occur in *P. totara* for example (Sub-Sect. D) in other species, e.g., *P. lawrencei* with which Florin (1940) especially compared his *E. confertus*, the leaf is usually thick.

The cuticle recalls both Stachycarpus and Subsection D if it is hypostomatic, but Stachycarpus only if it is unequally amphistomatic, while the close-set stomata in a narrow rectangular pit, perhaps are most like *P. totara* or *P. gniodiodes* of Subsection D, but comparison with species of Stachycarpus is certainly possible. It differs from both lacking the Florin ring.

The two pollen cone specimens referred to *E. confertus* do not belong with the shoots now separated as *M. podocarpoides*. They are seen in Halle (1913, pl. 8, fig. 31) and Sahni (1928, pl. figs. 5-7), and have been compared with the cones of *P. lawrencei* or *P. nivalis*. This can be maintained; so could a comparison with *P. ferrugineus* (for figs. see Wilde 1945). To me the pollen cones appear different from either group. Unluckily Sahni's figure of the pollen is too small to be of use.

The seed cone is in gross form similar to Stachycarpus, but in details, it is different from either that section or Eupodocarpus sub-section D.

However, though *Mataia* cannot be compared very closely with either group, it does share a number of features with them, and differs more widely from any other living genus or section. Perhaps *Mataia* preceded the evolution of Stachycarpus or of Sub-section D.

A further very interesting fact is that in a few features *Mataia* recalls *Saxegothea*. *Saxegothea* may show the same sort of false whorled branching (cf. Fig. 2F) the leaf is concave and hypostomatic; while the stomata of *Mataia* approach those of *Saxegothea* more closely than do any other podocarp figured, especially in the form of the papillae round the pit (Fig. 14B). In *Saxegothea* also the outlines may be pierced by holes (Fig. 14C) and may appear double. However, the stomata are closer packed in *Saxegothea* than they are in *Mataia* and the difference in cone structure is great.

(2) *The morphology of the seed cone.* In *Rissikia media* the cone scale (short shoot or seed scale complex) consisted of three lobes, joined below into a thick stalk. From the extreme base of each lobe two (in most cases, sometimes only one) stalked inverted seeds took their origin (Fig. 8G). In *Mataia* there are two stalked seeds in a similar position, but only one lobe on its (still thick) stalk. I think the easiest interpretation is that in *Mataia* we have one presumably the central one, of the three lobes of *Rissikia*, and the other two have vanished. (Fig. 14D).

On the other side, it is fairly easy to interpret the cone scale of *P. spicatus* and *P. andinus* in terms of *Mataia*. One seed has been lost, as sometimes is seen in *Mataia*, and the folded-over seed scale (epimatium) now envelopes the whole seed.

There may be some confirmatory evidence. No clear evidence can be seen of the bundles in *Mataia*, but as in *Rissikia* there is reason to think that each lobe contained two. In *P. spicatus* (Sinnott 1913) and *P. andinus* two bundles enter the base of the cone scale, which branch at the level of the chalaza; two passing to the chalaza, and two passing down into the (morphologically) distal parts of the epimatium (*P. spicatus*), or into its end beyond the seed (*P. andinus*). I regard the two bundles supplying the epimatium only as equivalent to the two (supposed) bundles in the lobes of the *Rissikia* cone scale.

There are difficulties about this interpretation The interpretation of the bundle course is not everywhere easy. Apparently normally in *Podocarpus* (though not very many species seem to have been examined) and in *Dacrydium bidwillii* two bundles supply the seed; and in *P. dacrydoides* and *P. lawrencei* for example, no others are present ascribable to the cone scale or seed. But in other species such as *P. totara* (Sub-section D, like *P. lawrencei*) and *P. elatus* (Eupodocarpus Sub-section B) the bundles perform a set of fairly complex evolutions between the levels of the micropyle and chalaza. In those genera and species in the case of *Dacrydium* without an epimatium, only one bundle supplies the seed (see Sinnott 1913, Florin 1950).

If the epimatium of *Podocarpus* is simply folded over the end of the cone scale, one might expect to see some sort of suture at the base of the whole cone scale or along the sides of the epimatium but one does not, at least in *P. spicatus* and *P. andinus*, the species chiefly concerned. In *Dacrydium bidwillii*, which here goes with *Podocarpus*, there are two lateral ridges, which could represent the position of the expected sutures, but, though these ridges contain various lacunae, the tissue between the ad- and abaxial sides of the seed is continuous through them.

Despite these uncertainties, in what follows the cone scale of *Mataia*, and of *Podocarpus* is regarded as equivalent to one of the three lobes seen in the flower of *Rissikia*. After all, this seems to be the simplest view.

GENERAL DISCUSSION

If *Rissikia* and *Mataia* belong to the Podocarpacaea, they raise a number of questions about the Family. The first is, where did it come from? The Southern Hemisphere Permian conifers seem unlikely. *Walkomiella* (Florin 1940, Surange and Prem Singh 1952) is different at every known feature. *Buriadia* Seward and Sahni (Florin 1944) and *Paranocladus* remain possible while only the shoot and cuticle is known. In neither feature do they especially recall *Rissikia*. Similarly, though the later Permian and Triassic conifers (*Voltzia* and its allies) are rather like *Rissikia* in the general organisation of their cones, the differences are considerable, and I doubt whether any direct

descent is likely either on morphological or stratigraphical grounds (but see Schweitzer 1963 for another view).

It seems to me one must consider the earliest conifers, *Lebachia* and especially *Ernestiodendron* (Florin 1938-1945). These conifers had pinnate, though probably unlimited, ultimate branches; they had leaves, rhomboidal in section, as in *R. apiculata*, and in some instances (Florin 1938-45, pl. 141/2, Fig. 17, pl. 133/4, Fig. 2: pl. 145/6, Figs. 7, 8) they seem to show a weak tendency towards flattening in one plane. The pollen cone of *Rissikia* is closely similar to the pollen cone of these conifers though the pollen differs. *Ernestiodendron* had a long spike-like cone, (Florin *loc. cit.* e.g. pl. 149/50, figs. 1, 5, 9) like *Rissikia*. The cuticle of these earliest conifers were not in general like the cuticle of *Rissikia* (but see *E. filiciforme* var. *gracile* Florin *loc. cit.* pl. 111/112, figs. 18, 19). Their cone scales also were not like those of *Rissikia*, though some could perhaps be considered similar, and in the *Ernestiodendron* group there is considerable variability (see e.g. *Walchiostrobus* sp. Florin *loc. cit.* pl. 163/164, figs. 3, 4, text fig. 34).

The matter remains open, though perhaps an origin in the complex of very early conifers from which *Lebachia* and *Ernestiodendron* sprang is the most likely.

As for evolution of organs in the *Podocarpaceae*, it now appears as Wilde (1945) visualised, that a richly branched habit, of the sort seen in *Podocarpus* Section Dacrycarpus (juvenile Fig. 2G), is a primitive feature. Whether all early Podocarpaceae had this form of branching in uncertain. Again, the bilaterally flattened leaf is seen to be extremely ancient, and considering the morphological (probably not phylogenetic) series *Ernestiodendron—Rissikia apiculata—R. media*, would seem to have evolved from the leaf rhomboidal in section, without reference to the bifacial leaf. For this reason, I, following Florin 1931, Gray 1962, and Hair 1963, doubt whether *Podocarpus* Section Dacrycarpus is rightly placed in *Podocarpus*. The features of the pollen cones seem to have changed very little. The scale has been reduced, and that is about all. We now know that within the Podocarapaceae, the disaccate pollen grain is very ancient, and most probably the primitive form.

In the seed cone, the special cone branch would appear (see Wilde 1945) to be retained, though often strongly reduced. I express no opinion on the details of Wilde's scheme however.

The chief contribution of the present fossils is to suggest, in a fairly direct way, that the single unit (i.e., bract plus cone scale with its seeds) of the *Podocarpus* cone can be regarded as equivalent to one of the lobes of the *Rissikia* cone scale (Fig. 15). That is, that the epimatium is a single but bivascular structure, not two univascular ones fused laterally as has sometimes been supposed (e.g. Florin 1950 for discussion of the point). However, the epimatial structures of the Podocarpaceae are varied. There is no suggestion that the method visualised here is the only means of attaining the epimatial state. Still less do I suggest that this process has happened only once.

In certain non-epimatial genera (e.g. *Microcachrys, Saxegothea* and *Dacrydium franklinii*) the cone scale is a trifid (non vascular) structure with one seed. It is possible to derive this from *R. apiculata* assuming the loss of two seeds (Fig. 15).

If this is so a trimerous symmetry would seem to characterize the Podocarpaceae. On these grounds, I would suggest that *Tricanolepis* Roselt (1958) should be reclassified under the Podocarpaceae, and not as he did, with the Taxodiaceae. Roselt largely relied upon the fact that in *Athrotaxis* three points to the cone scale may be found. This is true, but it is not the normal arrangement; which is for there to be four or five vascular bundles in the cone scale, and only one point. *Cunninghamia* (Taxodiaceae) also has three points to the cone scale. However, in other genera, notably in *Cryptomeria*, supposed to be very primitive, five lobes to the cone scale are present, or else five (or more) vascular bundles. The comparison of *Tricanolepis* with members of the Taxodiaceae is therefore with abnormalities; the comparison with the Podocarpaceae is between the normal situations. The distribution of *Rissikia* and a *Tricanolepis* is not a serious difficulty. *Rissikia* pollen belongs to a group that appeared first in the Upper Permian of Europe, Asia and America (e.g. Saarschmidt 1963, Jansonius 1962) and extended in those areas till the end of the Triassic. There is thus other independent evidence for the Podocarpaceae in the Northern Triassic.

On the pollen evidence, as on the comparison with the *Lebachia* group of conifers above, it seems possible that the Podocarpaceae were northern in origin reaching gondwana areas at the base of the Triassic (Balme 1963).

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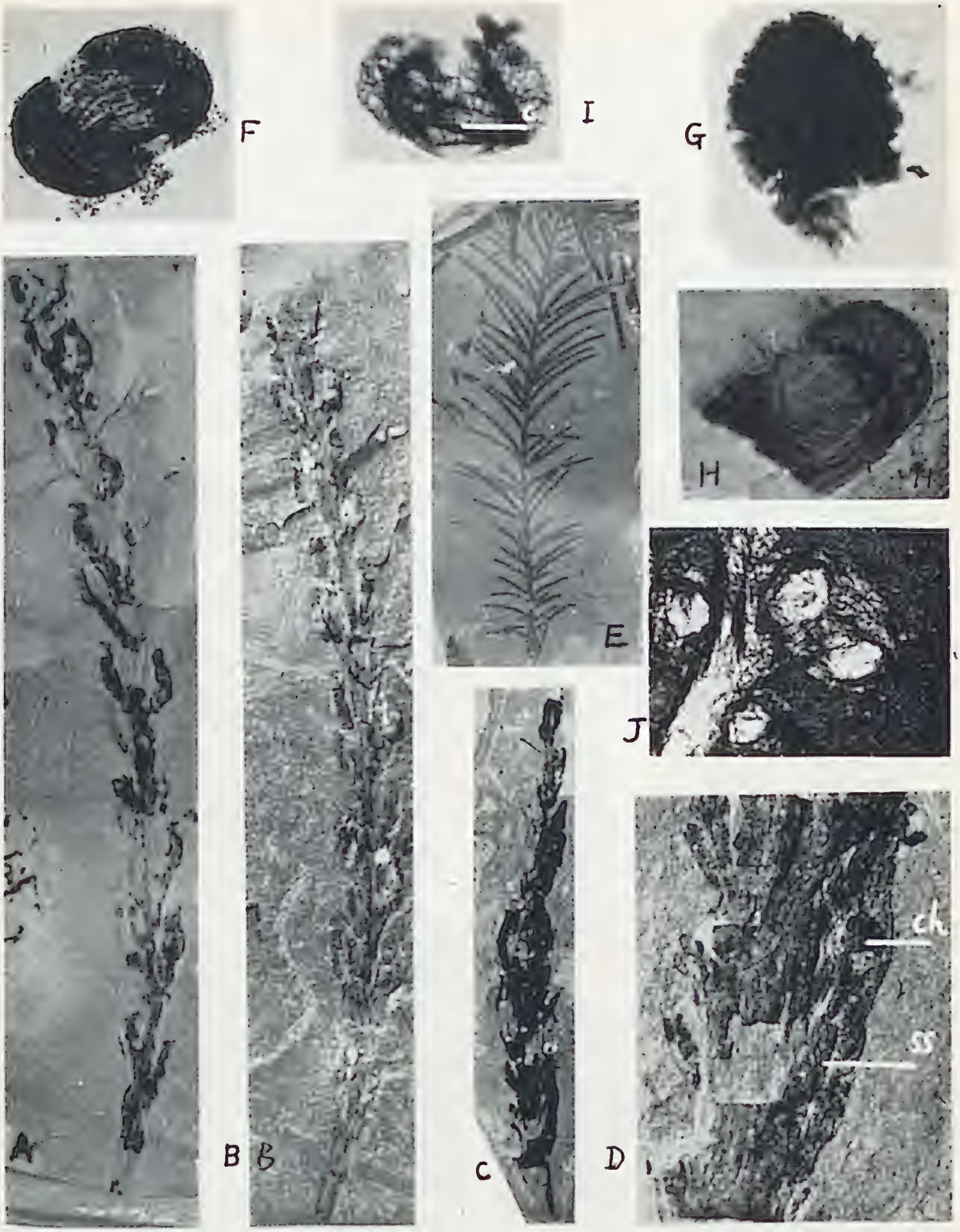

PLATE I.—*Rissikia media*, A, B, E-H; *R. apiculata* C, D. *Mataia podocarpoides*, J; *Striatites sewardii* of Pant I.

A, B. Part of the seed cone, under kerosene (A) and dry (B). x 2. Australian Museum F51972, 51973. C. A seed cone, taken under kerosene x 2. D, lower right part of cone, showing chalaza of seed (*ch*), seed stalk *ss*, and form of lobe of cone scale. x 6. Australian Museum F51983. E. A complete foliar spur x 1, Australian Museum F51960. F. Pollen grain with many striae. H. pollen grain with few striae, x 500. Australian Museum AM 6412. G. Seed somewhat compressed and crushed. Micropyle shown by black speck to right (cf. Fig. 9 J), and seed stalk on bottom left x 10, Australian Museum AM 6407. I. striate grain in slightly rotated proximal polar view, colpus = *c* x 300. Liveringa Fm. W. Australia prep. Dr. B. E. Balme. J. Cone unit with two seeds and overfolded portion. x 3. N.Z. Geol. Surv.

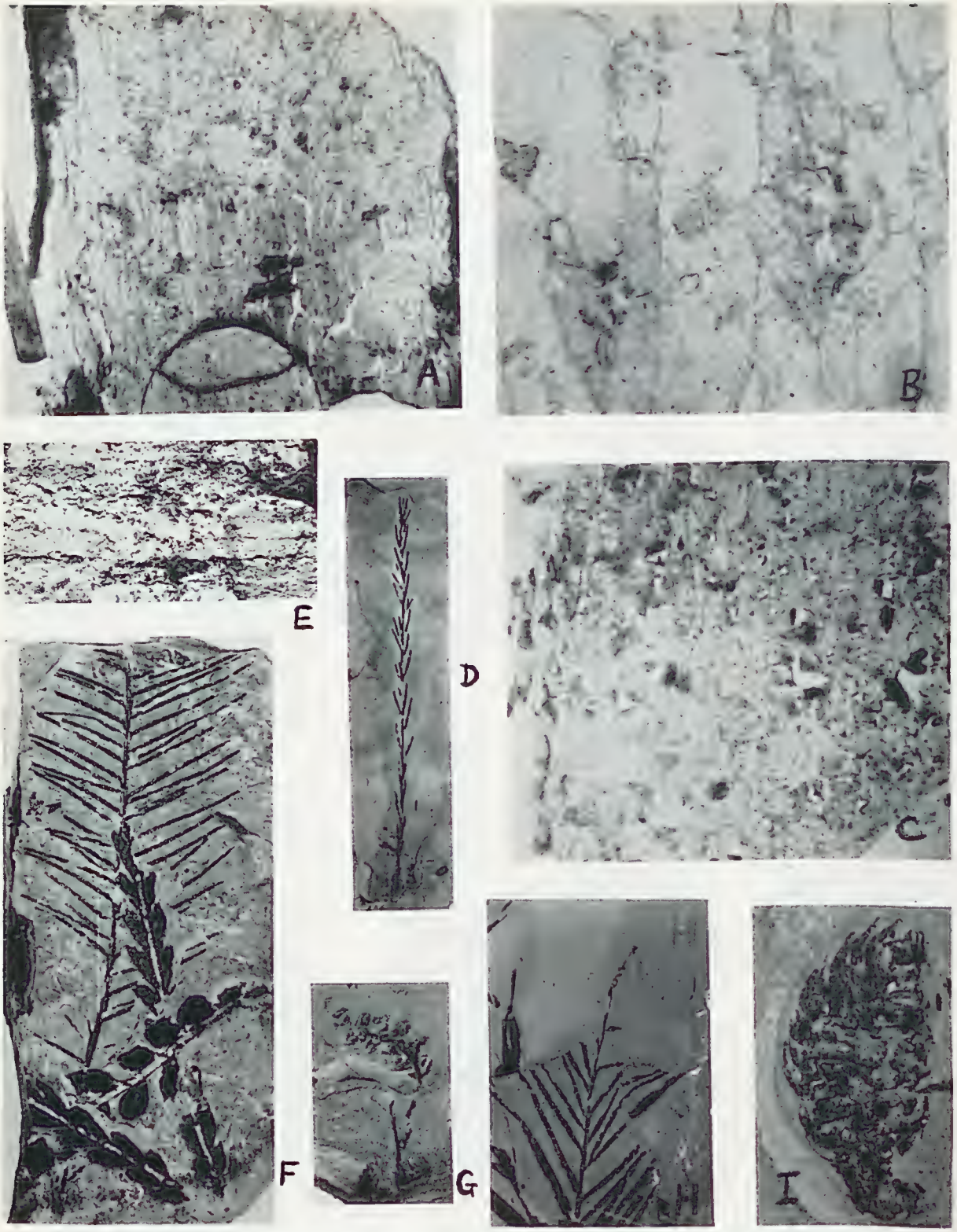

Plate II.—*Rissikia media* A-C, F, H, I: *R. apiculata* D (holotype): *Elatocladus planus* E; *Mataia podocarpoides* G.

A, C: cuticle from two pairs of flanks of one leaf x 50, Australian Museum AM 6409. B: Two stomata with surrounding lappets x 250, Australian Museum AM 6404. D. A foliar spur, x 1, Australian Museum F51976. E: parts of two leaves showing "cells" of replacing mineral x 20. University Tasmania. F, a foliar spur x 1 from Mt. Bumstead, E. Antarctica, Lat. 82° S. New Zealand Geol Survey B 822. G. A seed cone x 1, New Zealand Geol. Survey B 913. H, the apex of a foliar spur, just possibly growing on, i.e. not limited in growth x 1 Australian Museum F51966, I. The pollen cone x 2. Australian Museum F51972.

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ON A CONIFER FROM THE JURASSIC OF EAST ANTARCTICA

By

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(With one plate and five text figures.)

ABSTRACT

The genus *Nothodacrium* gen nov. is described, with one species, *N. warrenii* sp. nov., from the uppermost Beacon Group, of Jurassic age. Also described is the pollen cone *Masculostrobus warrenii* sp. nov., which may belong with *N. warrenii*. These fossils are ascribed to the Podocarpaceae, and their position in the Family is discussed.

INTRODUCTION

During the 1964-65 New Zealand Antarctic Research Programme the plant fossil locality at Carapace Nunatak was revisited and more material collected, part of which is dealt with here. The material consists of a cutinised shoot, an attached seed cone, not cutinised, and an isolated pollen cone, containing poorly preserved pollen grains similar to, but probably distinct from, *Tsugaepollenites trilobatus* (Balme) Dettmann. On the evidence of the seed cone and shoot, these two are believed to be podocarpaceous, and their structure, complementing that of *Rissikia* and *Mataia*, dealt with in the first of these notes on early mesozoic southern conifers, suggests one (but not necessarily the only) manner in which the non-epimatial podocarp seed cone may have evolved.

DESCRIPTIONS

Family Podocarpaceae

Genus **NOTHODACRIUM** nov.

Type species *Nothodacrium warrenii* sp. nov.

Diagnosis. Conifers, with terminal shoot systems not showing divisions into long and short shoots, each shoot showing distinct terminal bud. Shoots slightly flattened into one plane, branching more or less pinnate, but probably ultimately spiral. Diameter of terminal shoots (including decurrent leaf leaves) about 1.5 mm. Leaves borne spirally, all of one sort, directed forwards and diverging from the shoot at an angle of 10-30°. Leaves about 3 mm. long, 1.5 mm. wide and 1 mm. thick, more or less rhomboidal in section, often slightly falcate, (presumably) with one vein. Leaf bases strongly decurrent, down to next leaf on same side of the shoot, phylotaxis probably 3/8.

Cuticle similar all over the leaf, cells more or less rectangular, in rows, but narrower at the leaf margins, and over midrib. Stomata lying on four flanks of the leaf, in (probably) single rows, and about equally numerous all over. Cell outlines pierced by holes, but otherwise more or less straight; cells away from margin and midrib often bearing solid or hollow papillae, especially towards the leaf base. Stomata mono- or incompletely dicyclic, longitudinally or obliquely or transversely orientated, with guard cells sunken in a more or less rectangular pit, with walls formed by the subsidiary cells. Lateral subsidiary cells two to four, generally smooth, but rarely bearing a low and obscure Florin Ring (cutin thickening round the stomatal pit). Guard cells feebly cutinised.

Seed cone terminal on a branch of normal form, bearing leaves as on vegetative branches. Cone elongated, spike-like, consisting of 10-15 units. Units consisting of spirally inserted bracts and axillary cone scales free from each other. Bracts about 2 mm. long, and 0.5 mm. wide, simple, probably more or less strongly flattened bifacially. Cone scale flattened, consisting of three pointed lobes, about 2 mm. long, with the three points either bluntly or sharply pointed. Scale bearing single seed (as far as can be seen), about 1 mm. long and a little less at its widest; seed stalk (probably) adnate to scale, and seed (probably) inverted. Seed borne about centrally on cone scale. (Cuticle of seed cone unknown).

Nothodacrium warrenii sp. nov.

Pl. 1A, B, D. Figs. 1A-D; 2A-E; 3B-D.

1913 *Sphenolepidium oregonense* Halle, non Fontaine pp. 80-81, pl. 9, figs. 5b, 9-11 (shoots) and ?13 (cone). Hope Bay Graham Land.

?1913 *Conites* sp. Halle, pp. 81-82, pl. 9, figs. 12, 12a; seed cone. Hope Bay Graham Land.

1940 *Sphenolepidium oregonense* Florin non Fontaine, pp. 72-73. Discussion of Halle's material.

1947 *Elatocladus* sp. Jones and de Jersey, p. 9, figs. 15-17. Shoots from the Brighton Beds, Queensland.

1962 *Brachyphyllum cf. B. expansum* Plumstead non Sternberg, pp. 88-90, pl. 22, figs. 3 and 4.

1962 *Pagiophyllum* cf. *P. peregrinum* Plumstead non Lindley and Hutton, pp. 90-91, pl. 22, figs. 5 and 6.

1962 *Elatocladus* cf. *E. heterophylla* Plumstead non Halle, pp. 90-93, pl. 22, figs. 7-10. Material from Carapace Nunatak.

Type specimen. B 1012/10. New Zealand Geological Survey; see Plumstead (1962) pl. 22, fig. 3.

Locus typicus. Carapace Nunatak, E. Antarctica; Beacon Group, Jurassic.

FIG. 1.—*Nothodacrium warrenii* A-D: *Dacrydium novoguinëense*, E. F.
A-D: Parts of shoots showing a branching (A), a bud (D) and various forms of leaves; all x 7. A-C B1012/10, D1012/21. E, F: Parts of shoots with juvenile (E) and adult (F) leaves. x 7. Herb. C.S.I.R.O. *Robbins* 183.

Diagnosis. Terminal shoots about 1.5 mm. diameter, bearing more or less falcate leaves 1.5-3.5 mm. long, and 0.75-1.5 mms. wide and about 1 mm. thick at the base. Midrib generally visible as a raised line on the lower leaf surface, but upper leaf surface more or less flat. Leaf apex acute. Cuticle about 4μ thick, showing cells about 120μ long (80-150μ) and 40μ wide (20-65μ); outlines about 4μ wide. Stomata well separated from one another by about 8 (4-12) cells, including terminal encircling cells. Stomatal pit rectangular, about 60μ x 25μ, bounded at least laterally by a strong cutin rim. Papillae mostly solid, about 10μ high.

Cone (single specimen) 1.25 cms. long, those units (flowers) borne laterally lying about 1.5 mm. apart, but strongly decurrent. Bract and cone scale about 2 mm. long, seed scale complex about 0.5 mm. wide, bearing (presumed) seed about 0.25 from base of complex. Three points to cone scale free for usually less than half total length of scale. Cone axis about 1 mm. wide at base of cone.

Description.

(1) *The Carapace Nunatak locality.* On Carapace Nunatak the plants, with conchostrocans, are found in narrow shale or cherty bands underlying, and also interleaved with, a basalt flow (see Gunn and Warren 1962, p. 111). The degree of silicification increases nearing the basalt. Counting down from the base of the solid basalt, most plants come from the fourth and fifth shale bands, but isolated blocks of chert, probably from a higher band, have yielded plants. The material described by Plumstead (1962) came, in part, from a nearby moraine, but I surmise that most also originated in the fourth or fifth shale band. The plants are preserved in an unusual way. They may either be naturally macerated, or else not much compressed, and with the internal substance replaced by a siliceous mineral. At times, and in the material from (presumably) higher bands, the plant matter is entirely replaced by mineral. However, though indeterminable coniferous type petrified wood is present, the shoots are not petrifactions. The conditions of deposition are discussed by Gunn and Warren (1962) who believed following Plumstead (1962) that the plant beds were Lower Jurassic, but they may be younger than this.

(2) *The Material.* The material examined consists of B.697/1, 2 and 5, figured by Plumstead (1962, pl. 22) and this has no cuticle, and also B.1012/10, a cutinised shoot with B.1012/21 an uncutinised shoot with cone attached. This further material was collected by the Allan Nunatak Party, N.Z.A.R.P. 1964-65; the whole is now in the collections of the Geological Survey of New Zealand.

The small ultimate shoots are, so far as can be seen, all alike (Pl. IB and see Plumstead 1962, pl. 22, fig. 7), and visible on a number of them is a cluster of leaves, as over an apical bud (e.g. Fig. 1D). This suggests that, as in *Dacrydium cupressinum* for example, there was no division into long (main) shoots, and lateral (short) ones. However, the branches all emerge from the side, or near the side, of the parent shoot (Pl. IB, Fig. 1A and see Plumstead 1962, pl. 22 figs. 4, 8), suggesting that the whole shoot system may have been flattened somewhat as in *Podocarpus dacrydioides* (juvenile) and similar species.

The leaves are shown in Figs. 1A-D. They now lie all round the shoot, and since no twisting of cell rows at the leaf base can be seen, were so borne in life. Compressed laterally, the leaves show a median ridge (Fig. 1A, B) appearing in the cuticle as a zone of much elongated narrow cells (Fig. 2A right), interpreted as a thin, angular, but not scarious margin. Compressed dorsi-ventrally, the lower (abaxial) surface shows a raised area, sometimes sharp but more often not, over the midrib (Fig. 1C right), while the impression of the upper (abaxial) leaf surface shows an even less prominent ridge (Fig. 1C left). Again, in the cuticle there is a rather vague zone of narrow cells over the midrib (Pl. ID left), but from the absence of folding in the cuticle, it is supposed that the leaf, though rhombic in section, showed only a slightly projecting midrib on each surface. In shape it is reconstructed as being close to *Dacrydium novoguineënse* Gibbs (Fig. 1E, F), only without the scarious margin of that species.

The leaf shape varies considerably even on one shoot, and it is possible that some of this variation may be seasonal, small leaves tending to occur at branch bases, or over the buds. The midrib cannot always be seen on the lower surface.

The cuticle, as with other Carapace Nunatak material, was already largely macerated, and about an hour in dilute nitric acid followed by very dilute ammonia was sufficient treatment. Only small fragments covering both surfaces of the leaf could be obtained. However, on these fragments (Fig. 2A, C) the cuticle was similar all over, and in the larger isolated fragments, there was, with one possible exception, no distinction visible into an upper and lower cuticle. The exception is that on some pieces stomata were very few indeed, or even absent, and it is possible that rather more stomata lay on one pair of flanks than on the other. The difference, if any, was slight

As noted, both margins and midrib were visible on the cuticle. The cells lay in more or less regular rows, except at the leaf base, where, on the upper surface, the cells were irregularly set. The papillae (Fig. 2) were seen on most cells, about, but not always, centrally on a cell. The stomata are shown in Figs. 2B, D, E. In most the guard cells' cuticle has vanished, but in a few, the stomatal aperture is seen to be parallel with the long axis of the pit. This was variably orientated, though most often more or less longitudinal, and presumably the guard cells were also variably orientated. In most stomata the subsidiary cell surface is smooth (Fig. 2B, E), but in some three or four a low obscure Florin ring, like that in e.g. *Dacrydium cupressinum* could be seen (Fig. 2D). In one place a cutinised hypodermis seems to be visible.

Though coming from one specimen the cuticle shows variation, especially in cell size and shape and in form of papillae as well as in the number of holes through the outline (Figs. 2A, B), such holes causing the cell outlines to appear sinuous at low magnification. The cuticle is in places damaged by re-crystallised silica grains.

The seed cone, as noted, is not preserved with cuticle. The mineral infilling indeed tends to blur the outlines of the parts, though examined under kerosene these can still be made out. However, parts (e.g. possibly seeds) can be lifted out, probably intact, so that the material can be, in a way of speaking, dissected apart.

The cone is in contact with more shoots (Pl. IA), though the extent of contact is not large, and for this reason one name is used for both shoot and cone. These shoots though uncutinised show the features of the other material of *N. warrenii* other than cuticular and the branch bearing the cone has leaves towards its base like those on other branches. The fertile branch was like an ordinary vegetative branch.

The units (flowers or seed scale complexes with their bracts) stand out at about 70° from the shoot. The bract is seen compressed laterally in Fig. 3C, and in this view looks much like a vegetative leaf. In Fig. 3D two are seen probably compressed more or less dorsi-ventrally, and here, though the lower surface is raised, the bract does not show the midrib as clearly as the leaves do. Presumably it was more flattened. In several places the cone scale is seen to end in three distinct points (Pl. IA and Figs. 3B, C, D). The whole structure is now flattened on the rock, and may have been flattened in life, for turned-in edges (*cf. Rissikia*) are not seen. The points, however, may be obtuse (Fig. 3D) or acute (Fig. 3C). The nature of the seed is still uncertain. In a number of places (Figs. 3C, D) there is either a hollow, or a raised piece of matter, which can be lifted out intact which looks as if it contained, or was, the seed. On this view there was only one per complex. The narrow end of this putative seed pointed towards the cone axis, seen especially clearly when the unit is compressed laterally (Fig. 3D), and from this it is deduced that the seed was inverted. In one unit compressed laterally (Fig. 3B) there is a deep trench between the seed and the scale, and this may represent the position of a free stalk. On the other hand, in other places (e.g. Fig. 3D, shown by lines) there are wisps of tissue showing elongated cells, and these wisps are connected with the scale below. On the whole, I think it is more likely that the seed stalk was adnate to the scale, and the trench referred to might be caused by the inrolling of a laterally compressed structure. The matter must remain open. There is no evidence on the venation of the seed scale complex.

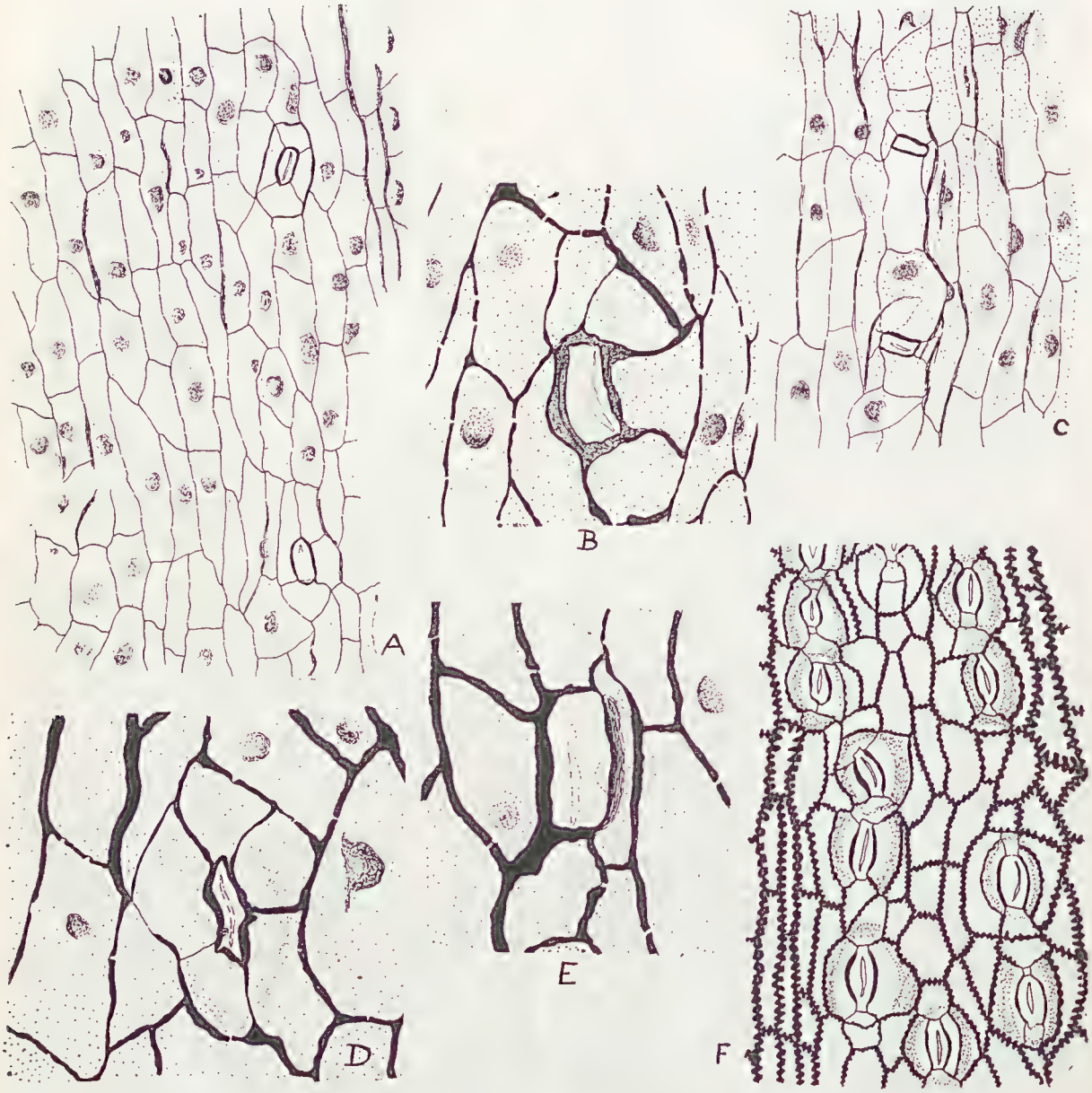

FIG. 2.—*Nothodacrium warrenii* A-E; *Dacrydium araucarioides*, F.

A, C: Cuticle from the plants of the leaf, showing stomata and papillae. x 300. B1012/10. B-E: Three stomata, obscure Florin Ring (D) x 600. B1012/10. F: Cuticle showing a few stomata not strictly alligned. x 300. Nat. Herb. Melbourne.

The impressions considered to be the marks left by seeds vary in size, being smaller than the dimensions cited above towards the base of the cone. One explanation is that, as in *Dacrydium franklinii* today, not every ovule ripened (Fig. 5).

The name is compounded of *nothos* = false and *-dacrium* shortened from *Dacrydium*.

(3) *Specific comparisons.* The material figured by Plumstead (1962) does vary considerably in leaf shape, but so does mine (cf. Figs. 2B-D and Plumstead 1962, pl. 22); one fragment (Fig. 1B) showing especially short wide leaves is seen to be identical on its cuticle. The total variation is, however, scarcely more than one would find in a living tree with similar sorts of leaves, and though identity of Plumstead's material with mine cannot be absolutely proved, in absence of cuticle, I believe it is extremely likely that it does all belong to one species. It all differs from *Brachyphyllum expansum* and *Pagiophyllum peregrinum*, with which she compared some, though without referring to the recent revisions of these species (Kendall, 1948, 1949).

The identity of Halle's (1913) material from Graham Land and of Jones and de Jersey's (1947) from Queensland with *N. warrenii* is open to question, for details are not available for it. However, in size, leaf and shape and, less certainly, cone form, it agrees, and is therefore identified. Halle's figures, however, show less richly branched shoots.

The name is given for Mr. Guyon Warren, who discovered the Carapace Nunatak locality, and the first material. He also organised the project to re-explore the area, and it was a great pity that he was prevented from taking part by an unfortunate accident. The least I can do is to name the material after him.

There would seem to be only one species with which *N. warrenii* could be confused, and that is *Elatocladus heterophylla* Halle (1913, see discussion by Florin, 1940). This species lacks cuticle details, but can be distinguished because its parts are about twice as large as those of *N. warrenii*. Going on figures only, it seems to show a distinct tendency to produce long and short shoots (Halle 1913 pl. 8, figs. 13, 14, text fig. 18), and on some of the short shoots the leaves are interpreted by Florin as bilaterally flattened (pl. 18, figs. 18, 20, 22a, text fig. 18), whereas in *N. warrenii* any flattening is bifacial. Menendez (1957) figures a small shoot, with cuticle, but no stomata. In cell shape and arrangement the cuticle is much like that of *N. warrenii*. Florin (1940) states that *E. heterophylla* is much like Podocarpus Section Dacrycarpus, however *N. warrenii* foliage is more like *Dacrydium* group B. The cone of *E. heterophylla* is unknown.

(4) *Generic comparison.* In both foliage and cone *Nothodacryium* closely approaches *Dacrydium*, especially *D. elatum, D. cupressinum* and their allies (Group B of Florin 1931). The general outline, and branching pattern of the shoots is however not entirely the same as this group of *Dacrydium*, but the leaf form is close. The cuticle differs, notably in showing stomata of variable orientation, (though *D. araucarioides* may show a slight approach Fig. 2F), in having papillae, and in lacking (in most stomata) the Florin ring (see Florin 1931 and Figs. 2B, E). The cone is less easy to compare, since a number of points are uncertain. However, accepting the reconstruction offered here, the long rather loose form of the cone can be matched in *D. franklinii*, where, however, the cone is smaller. The division of the cone scale into three points is also sometimes seen in *D. franklinii*, though the points there are very much smaller and, rarely, also in D. *laxifolium*. The (probably) inverted seed, unenclosed by an epimatium, is not found in living *Dacrydium* species, but in ontogeny, the ovule of *D. cupressinum* starts inverted, and only later becomes partially upright.

It is, in fact, so easy to interpret the cone and foliage of *Nothodacrium* in terms of *Dacrydium*, that *Nothodacrium* is placed in the Podocaraceae with some assurance. However, the differences just outlined make it undesirabe to include it in *Dacrydium*, which is in any case inconveniently heterogeneous.

Tricanolepis monosperma Roselt (1958) comes close to *Nothodacrium*, but differs in that the bract is adnate to the cone scale, the cone has many more units, and the stalk of the units is longer.

(5) *Morphology of the seed cone.* As noted, the seed cone is readily to be described in terms of the seed cone of *Dacrydium*, especially *D. franklinii*. The differences are essentially that the cone is larger, and the cone scale more complicated. The difference, on the other side, between *D. franklinii* and *D. cupressinum*, for example, is that the cone of *D. cupressinum* is reduced to one fertile unit, and the cone scale to a small unlobed frill at the base of the seed. There is thus a series, partly also a series in time, from *Nothodacrium* to species such as *D. cupressinum*. I interpret this as a series, illustrating evolution in the female cone.

However, it is also easy to describe *Nothodacrium* (Jurassic) in terms of *Rissikia* (Triassic). The chief difference between the two in their seed cones lies in this. *R. media* has two seeds associated with each of the three free lobes of the cone scale, but *Nothodacrium* shows adnation between the three lobes of the complex, and has lost five out of the six seeds. *R. apiculata* to some extent bridges the gap, since it has (as far as can be made out) only three, or even fewer, seeds per unit.

? PODOCARPACIAE

Organ Genus *MASCULOSTROBUS* Seward

Masculostrobus warrenii sp. nov.

Pl. 1C, Figs. 3A, E; 4B, D, E.

Holotype: B 1012; 19 Geological Survey of New Zealand, Pl. 1C.

Type locality: Carapace Nunatak, E. Antarctica; Beacon Group, Jurassic.

(1) *Diagnosis*: Conifer pollen cone, 8 mms. long, oblong, 5 mm. wide at widest part, bearing (estimated) 30 sporophylls. Cone base showing three sterile leaves, 2 mm. long 0.25 mm. wide, rhomboidal in cross-section but cone not showing a stalk. Cone axis stout 1-5 mms. in diameter at base, showing elongated cells. Sporophylls emerging at about 110° at cone base, decreasing to about 45° at cone apex; each sporophyll consisting of connective, about 0.5 mm. in diameter showing

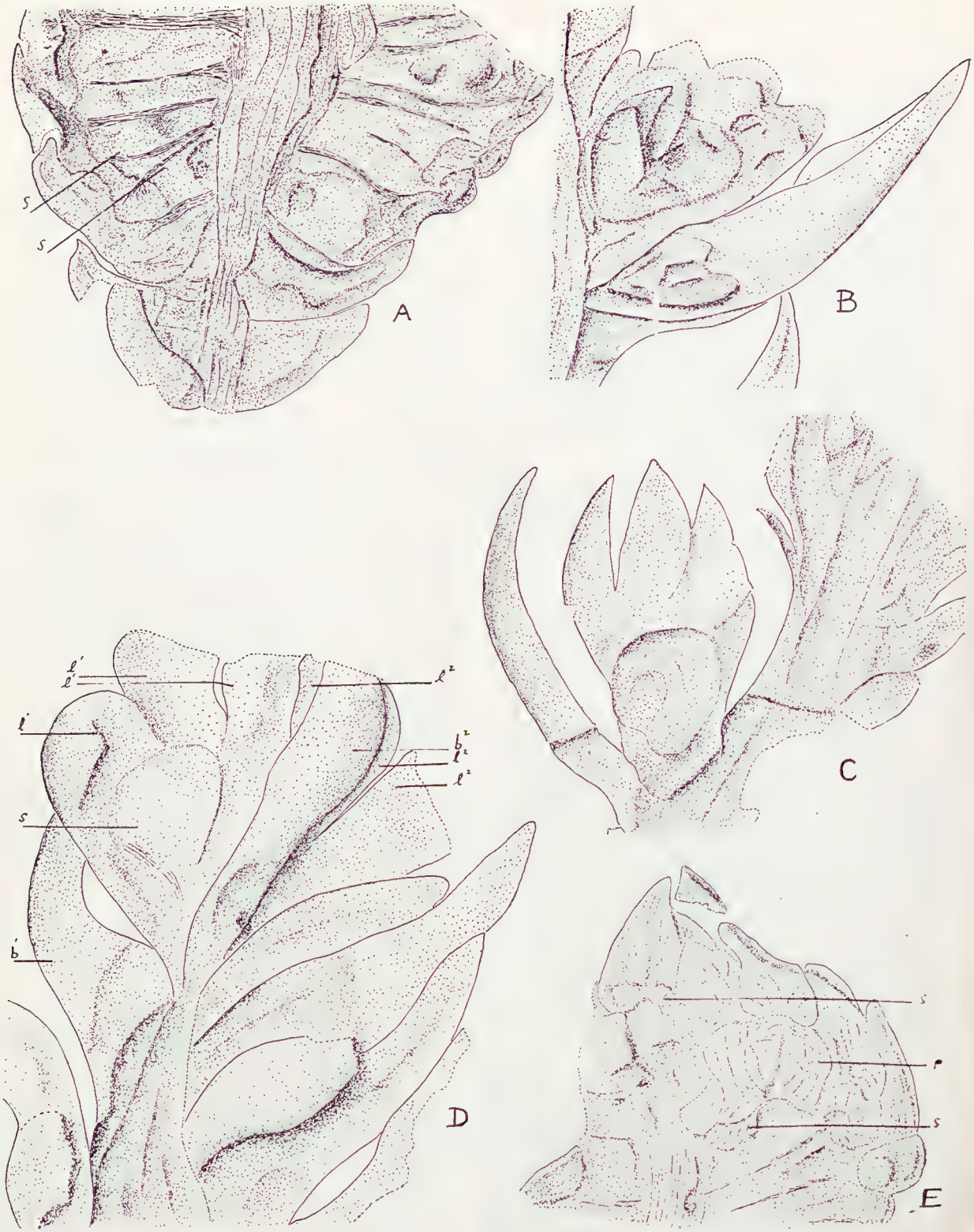

FIG. 3.—*Nothodacrium warrenii* B-D: *Masculostrobus warrenii*, A, E.

A: Base of the cone, showing leaves like leaves on shoot of *N. warrenii* at base. x 10 B.1012/15. B, C: Part (C) and counterpart (B) of same cone unit. x 7. D: Apex of the cone, b^1, b^2—, bract of units 1 and 2; 1^1, 1^2— lobes of cone scale of units 1 and 2; s = seed (lines indicate region where elongated cells are present). x 7. B.1012/21. E. Apex of the cone, s = imprint of pollen sac, P = scale x 10. B.1012/15.

elongated cells, peltate scale, triangular in shape, attached to connective a little below the mid-point, about 1.5 mm. high and 0.5 mm. wide, and (probably) two pollen sacs. Apex of peltate scale more or less pointed, outward surface showing rows of cells radiating out from point of connection with connective, scale margin ragged by reason of ex-current cell rows. Scale not connected to pollen sacs. Pollen sacs about 1 mm. deep, probably connected along whole length of connective. Cuticle unknown.

Pollen of more or less rounded outline, diameter about 110μ (78μ to 153μ), amb equilateral triangular, but with well rounded corners, of side about 88μ (62μ to 110μ), and usually reaching outside edge of grain at three places. Grain with three sacci, rarely confluent. Sacci about 16μ (3μ to 24μ) wide, not always of equal size. Sacci sometimes showing small radial foldings. Exine of amb 1.5μ thick, at saccus edge (exoexine) 2μ; sometimes very faintly showing more or less reticulate pattern, and sometimes faint triradiate mark, with arms running more or less straight and reaching almost to the equator.

(2) *Descriptions and Discussion*: The material consists of a single cone, part and incomplete counterpart, coming from the same shale band (and within a few feet of) some of the material of *Nothodacrium*. Unluckily replacement has gone so far that all efforts to obtain cuticle were unsuccessful, though cells can still be seen, under kerosene, and in one pollen preparation elongated cells possibly of a pollen sac could be made out. It is possible that the cone had shed most of its pollen before fossilisation, for mineral matter occupies the space on most sporophylls where the pollen sacs should be.

Just as in *N. warrenii* the sterile leaves show a ridge down the mid-line whether viewed laterally or from upper or lower surface (Fig. 3A). This presumably means they were rhomboidal in section.

The form of the scale is given as peltate, and not attached to the pollen sacs because in several sporophylls, viewed from the outside, there is a depression from which cell rows radiate, just as over the point of attachment of connective and scale in a living conifer, and this depression is set some way from the base of the scale (Fig. 3E). Further, the scale overlaps, at a different level, the pollen sac (Fig. 3E). The reason for thinking that there are only two pollen sacs is that two depressions flank the point of attachment of the connective (Fig. 3E). It is not clear, however, what the shape of the pollen sacs is, from the sac at *s* in Fig. 3A it is thought that they probably extended the whole length of the connective.

By analogy with living podocarps having the male cone terminal on a normal branch (e.g. *Dacrydium*, or *Microcachrys* (Fig. 4G) I think it probable that *M. warrenii* was also terminal on a normal leafy shoot. For in the living species the cone tends to disarticulate leaving no stalk, but carrying with it three or four scales of form similar to the ordinary leaves, but often slightly smaller. In species such as *P. lawrencei* Hook. or *Saxegothea* Lindl., the scales tend to be left behind. Three sterile scales are seen in *M. warrenii*.

The pollen proved troublesome to prepare. Finally, pieces of mineral matter replacing the pollen sacs were removed and treated on a plastic side with HF to spread the siliceous matter, followed by a mixture of equal parts of water, HF, HNO_3 (as for *N. warrenii*). This gave modest success, but the grains are not well preserved.

A variety of pollen was found, namely two lycopsid microspores, two grains referable to a species of *Classopollis* Pflug, one cycad-like, as well as sixteen grains closely resembling *Tsugaepollenites* Potonié. The *Tsugaepollenites* grains are considered to belong to the cone because (*a*) they are the most numerous sort seen, and (*b*) seven are still united in tetrads. This evidence is not very satisfactory.

The pollen is closely similar to *Tsugaepollenites trilobatus* (Balme) Dettmann (see Balme 1957, Dettmann 1963, full account with further references). Thanks to the kindness of Dr. B. E. Balme, and of Dr. M. Dettmann, I was able to examine material of *T. trilobatus* and also of the similar *T. dampieri* which has fully confluent sacci. Most grains were like the ones shown in Figs. 4B, D, but others (Fig. 4E) show only very faint sacci, and a nearly perfectly circular outline, while others again show more or less confluent sacci. A feature sometimes seen in my material, and not plainly seen in material of *T. trilobatus* is the numerous small radial folds rather like those seen in e.g. *Dacrydium cupressinum* (Fig. 4B, but see Dettmann 1963 pl. 24 figs. 7 and 8). Also the extine ornament is not seen in my material, it is too ill preserved. However, when all this is said, correspondence is close in general form, dimensions and in such detail is visible, including triradiate mark.

I do not identify the grains with *T. trilobatus* because there do seem to be some definite differences (e.g. the folding of the saccus) and some of the features upon which the diagnosis of *T. trilobatus* depends are not visible.

Gamerro (1965) has found *T. trilobatus* in a cone belonging to *Apterocladus lanceolatus* Archangelsky, and has shown that *T. trilobatus* and *T. dampieri* (Balme) Dettmann are identical. This material comes from the Lower Cretaceous of the Argentine. Archanglesky and Gamerro consider that *Apterocladus* belonged to the Podocarpaceae, and for *M. warrenii* I agree that *Tsuguepollenites trilobatus* (with *T. dampieri*) is most probably podocarpaceous (below).

Cranwell (1961) raises the possibility that in the Podocarpaceae the single encircling saccus is the primitive form of the saccus. It is certainly an ancient form, but I do not think original in the Podocarpaceae, since *Rissikia* has disaccate grains. In this connection it is of great interest to find that *Acmopyle*, usually disaccate, does sometimes produce trisaccate grains, with sacci still separate (Cranwell *loc. cit.*). The encircling saccus in the Podocarpaceae is here regarded as derived, from either a di- or a trisaccate original.

It seems possible that the tri- to monosaccate grains of the *T. trilobatus* sort are to be compared most closely with the fully trisaccate grains of *Podocarpus* of the Section Dacrycarpus, differing in that the sacci become confluent and smaller. In *P. dacrydioides*, for example (Cranwell 1961), grains

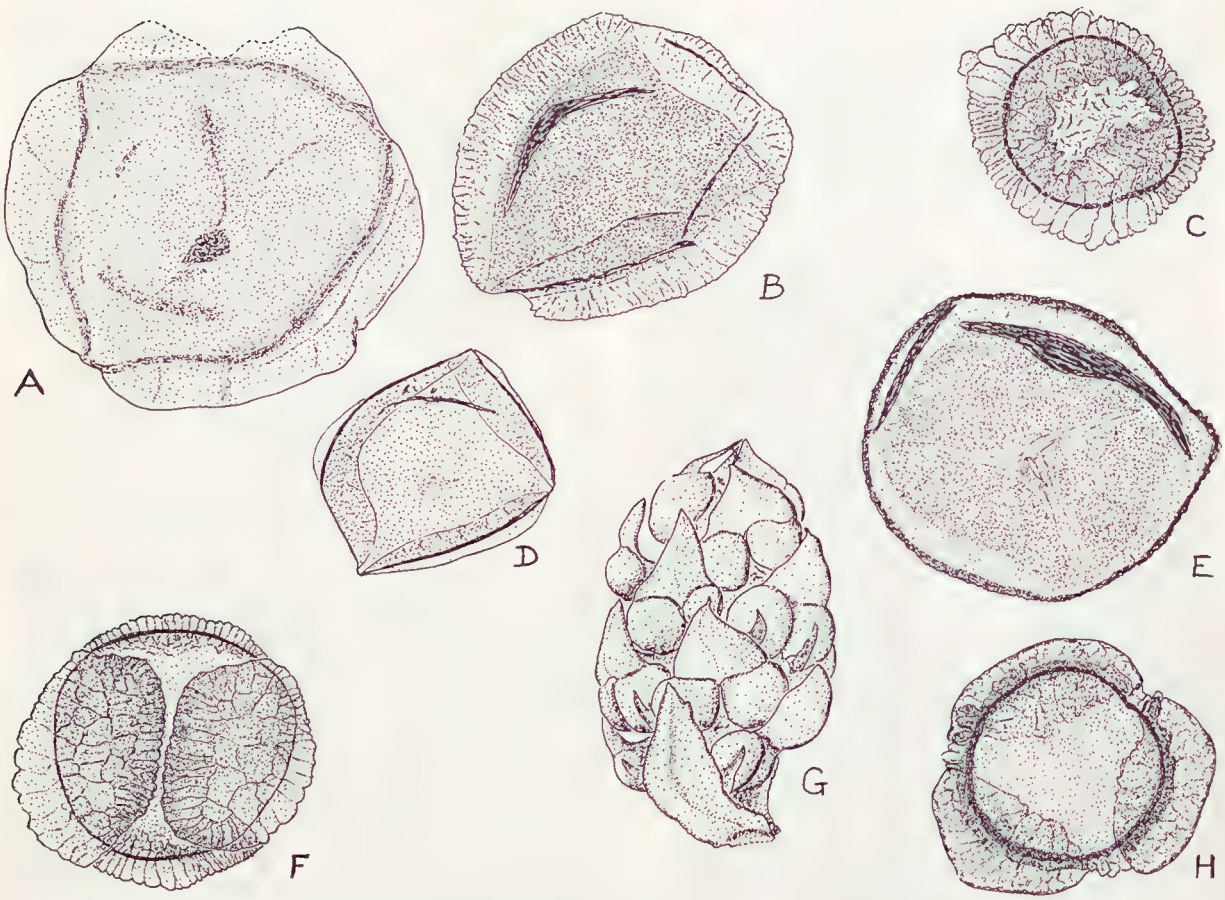

FIG. 4.—*Tsugacpollenites trilobatus* A; pollen from *Masculostrobus warrenii* B, D, E; *Dacrydium araucarioides*, C; *D. cupressinum*, F; *Microcachrys tetragona* G; *Podocarpus dacrydioides* H.

A: Pollen grain in polar view. *Dettmann* Kopperamame Bore 2970 ft. D 2346. B: Grain with sacci well seen; sacci showing many small radial folds. D: Grain with distinct sacci folded in over corpus (Several grains seen deformed so). E: grain with very obscure sacci, but showing triradiate mark. C, F: Grain in distal polar view, sacci to left and right. G: A cone, disarticulated to carry with it the (two in *M. tetragona*) leaf-like scales at base (cf. Fig. 3A) x 7. H:grain in proximal polar view, showing sacci continuous round equator. All pollens x 600. B, D, E B 1021/15. C, Bucholz 1059; F, Dominion Museum No. 2; H, *Smith* 78627, Herb. DSIR, New Zealand.

can be found not uncommonly in which the sacci are confluent in the equatorial region (Fig. 4H); and in this species also a triradiate mark may be found (Cranwell *loc cit.*). There is moreover a partial analogy in some species of *Dacrydium*, from *D. cupressinum* (Fig. 4F) with connected but large sacci, via *D. araucarioides* or *D. balansae* in which the sacci are smaller and connected by a wide frill (Fig. 4C) to *D. guilleaumii* Bucholz in which the frill-like saccus is the same width all the way round the grain (Erdtman 1957, figs. 25 and 26). The analogy is only partial because these grains are essentially di- not tri- saccate, and the sacci are strongly offset distally, and are not equatorial.

This view has nothing to say on the ultimate origin of the saccus, which Gamerro (*loc cit.* following Wodehouse) considers arose through a separation of extine and intine around the colpus.

Masculostrobus warrenii is thought to belong to the Podocarpaceae. This is because there are, as far as can be seen, only two pollen sacs, possibly attached along the whole length of the connective; the form of the scale recalls *Rissikia* and also some living podocarps, e.g. *D. cupressinum*, and the supposed pollen as noted, is more like that of members of the Podocarpaceae than other conifers. The manner of disarticulation is also consistent with the view that it is podocarpaceous.

There is a strong possibility the *M. warrenii* is the pollen cone of *Nothodacrium*. The chief evidence is that the sterile scales at the base of the cone are of the same shape as, and slightly smaller than the leaves of *Nothodacrium*. The size of the cone stalk is, also, the same size as the axis of the ultimate branchlets of *Nothodacrium*. Also, as noted, the two are associated. Without agreement

in microscopic detail it would be wrong to call them by the same name. It might be argued that *Nothodacrium* should be referred to *Apterocladus*, but this is not done, largely because it is not certain that *M. warrenii* does belong with *Nothodacrium*, and because *Nothodacrium* is largely defined on its seed cone characters, unavailable to Gamerro, and the leaves differ.

GENERAL DISCUSSION

As it is interpreted, the cone scale of *Nothodacrium* is like that of *Rissikia* on the one hand, especially *R. apiculata*, and *Dacrydium franklinii* with *D. cupressinum* on the other. In Fig. 5 this series is shown. I suggest that this series might be regarded as an evolutionary one, indicating how the non-epimatial sort of cone scale arose, though no claim is made that this is the only possible scheme, or the only set of changes that has taken place.

Taking the position here suggested, *Mataia* and *Nothodacrium* complement one another, and both point back to the *Rissikia* seed cone scale unit as being an original form which most (not all) cone scales of the living Podocarpaceae can fairly simply be derived. In the epimatial unit, it is possible that one of the three lobes of the *Rissikia* unit is retained, originally with two seeds, (*Mataia*), later with one only (*Podocarpus*): while in the non-epimatial unit it may be that all three lobes of the *Rissikia* unit are retained, but reduced in size finally to a small frill, while the seeds are reduced to three (*R. apiculata*, probably) then one (*Nothodacrium* and *Dacrydium*).

It is very interesting that the genus *Tricanolepis* Roselt (1958) shows a set of changes very similar to those observed between *Rissikia* and *Nothodacrium*, as well as showing their essentially trimerous symmetry. This may be a case of parallel evolution, but to me suggests that *Tricanolepis* should be placed with *Rissikia* and *Nothodacrium* in the Podocarpaceae, not the Taxodiaceae (Roselt *loc. cit*). If so, this is evidence in addition to pollen (e.g. Gamerro 1965) that at some stages in the Meozoic the Podocarpaceae were world wide (but see Florin 1963).

Assuming that *Masculostrobus warrenii* belongs with *Nothodacrium warrenii*, the fossil shows points recalling three groups of podocarps. It has the pinnate branching pattern, flat subsidiary cells and (as it is argued) a similar pollen organisation to *Podocarpus* Sect. Dacrycarpus. The rather simple arrangement of subsidiary and encircling cells also recalls Dacrycarpus. However, in that the ultimate shoots are of unlimited growth, and in the leaf shape *Dacrydium* group B (*D. elatum*, *D. cupressinum* and their allies) is recalled. This group, unlike Dacrycarpus has non-epimatial cone scales, one fertile cone scale per cone. *Dacrydium franklinii* is recalled in that the spike-like cone consists of several fertile units, and each cone scale is trifid. However, in other available features *N. warrenii* diverges from *D. franklinii*, and I am inclined to minimise the resemblances since, as above, three lobes per cone scale seems to be basic to the Podocarpaceae, and the reduction from several to one fertile unit has almost certainly proceeded at least twice independently (in *Podocarpus* Section Stachycarpus, and in *D. franklinii* versus *D. laxifolium*). In having (as it is thought) an inverted seed *N. warrenii* comes perhaps closer to *D. cupressinum*, in which the seed is first inverted, but in ontogeny becomes semi-upright, than to *D. franklinii* in which, as far as is known, this change does not take place. The pollen cone does not especially recall any of the above groups showing points of resemblance to all, and a single terminal cone on an ordinary branch, as *M. warrenii* is thought to have been, is found in all three.

It seems therefore, that the two groups particularly recalled are *Podocarpus* Section Dacrycarpus and *Dacrydium* group B, and except for the more doubtful case of *D. franklinii*, no others seem to be concerned. This is interesting, for Hair (1963) has shown that Dacrycarpus and *Dacrydium* Group B have particularly similar chromosomes, and he tentatively groups them together. It seems that the fossil evidence offers a little support to Hair's view.

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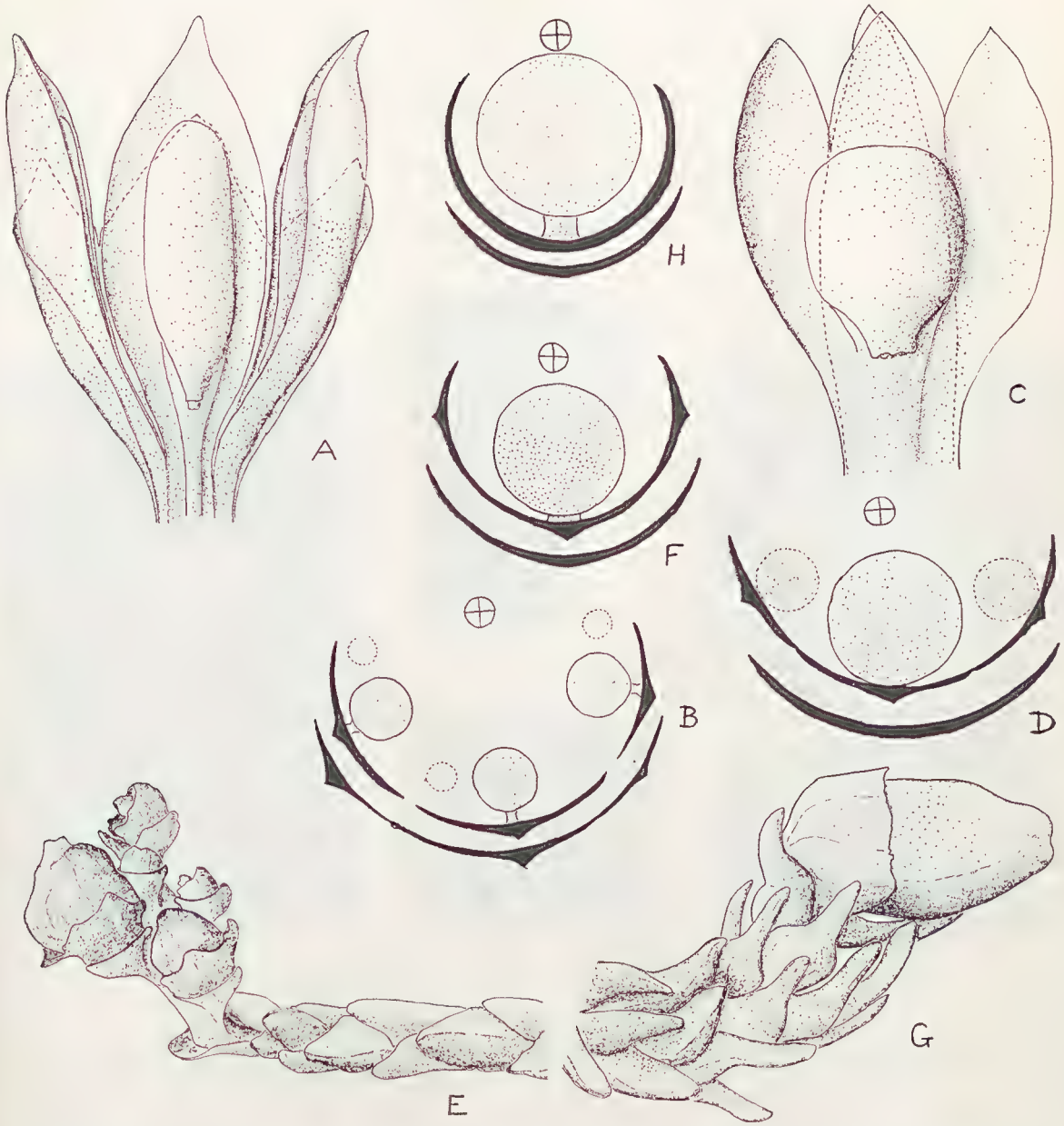

FIG. 5.—A: *Rissikia apiculata*, reconstruction in adaxial view of one unit (cone scale and bract) x ca. 18. B: *R. apiculata*, floral diagram (using Florin's terminology) of unit in 5A. C, D: *Nothodacrium warrenii*, reconstructions as in 5A, B. E: *Dacrydium franklinii*, a cone, x 7, and F: floral diagram. F, G: *D. cupressinum*, floral diagram and cone.

NOTE: seeds shown dotted in B and D are those supposed lost as between *Rissikia media* and *R. apiculata* (B), and *R. apiculata* and *Nothodacrium* (D). No effort is made to interpret the cones in terms of their (supposed) original radial symmetry.

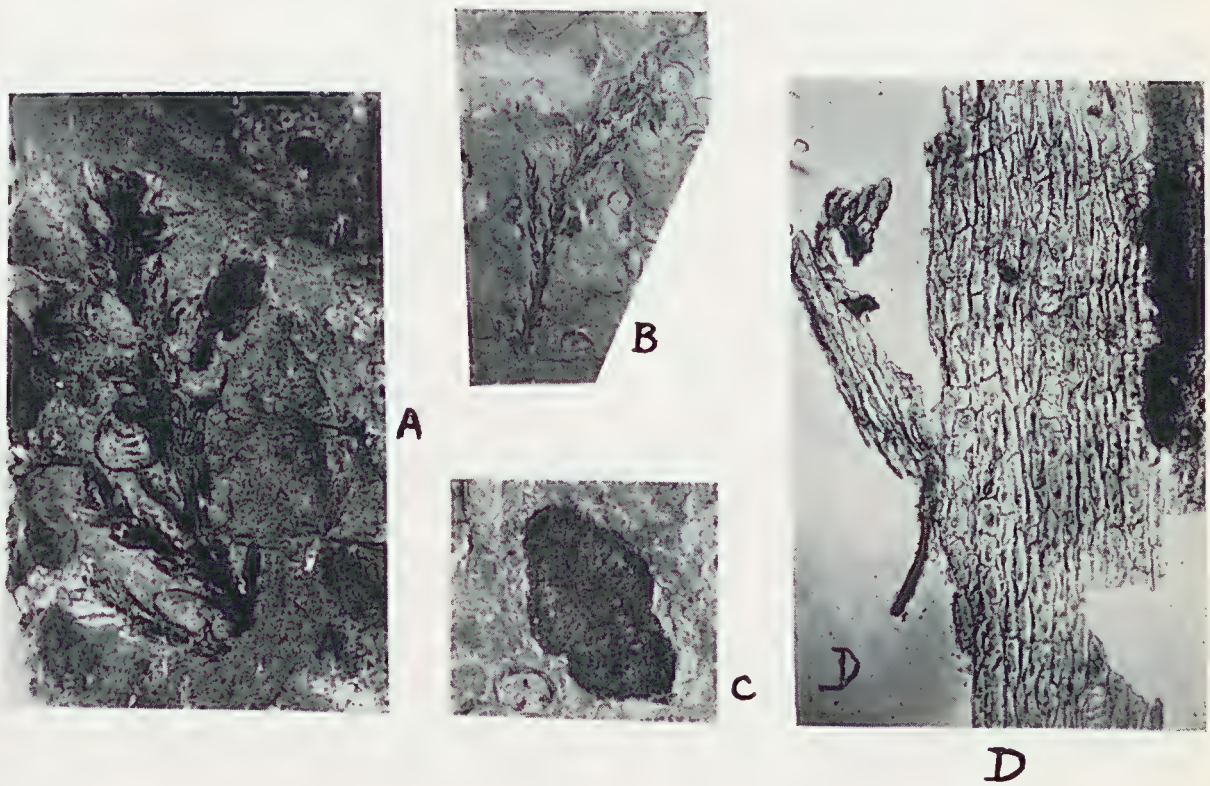

Plate 1.—A: *Nothodacrium warrenii*, shoot with base of the seed cone, B1012/21 x 2. B: *N. warrenii*, cutinised shoot x 1, B1012/10. C: *Masculostrobus warrenii*, the cone B1012/15. x 1.25. D: cuticle cells papillae and stomata. B1012/10. x 50.

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THE BRACHYPHYLLUM CRASSUM COMPLEX OF FOSSIL CONIFERS

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(With one plate and 11 text figures.)

ABSTRACT

The holotype of *Brachyphyllum crassum* Tenison Woods, is re-examined, and this species reclassified as *Araucaria crassa* (Tenison Woods) com. nov.; it is probably Tertiary in age. Of shoots referred to *A. crassa* one belongs to the Taxodiaceae, *Athrotaxus tasmanica* com. nov. also almost certainly Tertiary; while the other, Jurassic in age, is referred to *Pagiophyllum feistmanteli* Halle, which is redescribed. Another group of shoots sometimes confused with *A. crassa* is described as *Allocladus* gen. nov., with three species *Al. rajmahalense* (Feistmantel) com. nov. *Al. milneanus* (Tenison Woods) com. nov. and *Al. cribbii* sp. nov. The supposed cone of *Al. milneanus* is examined, and doubt is thrown on its ascription to *Allocladus*. It is renamed *Conites tenison-woodsi* nom. nov.

INTRODUCTION

One of the earliest fossil conifers to be described from Australia was *Brachyphyllum crassum* (Tenison Woods 1883), but though the original description was a good one for its date, the species has never been adequately redefined. This is now attempted, from an examination of the holotype. From this it appears that this species is almost certainly a Tertiary *Araucaria* sect. Eutacta, close to *A. montana* Bgt. and Gris and *A. berneri* Bucholz. Of the various shoots confused with *A. crassa* (Tenison Woods), when microscopic detail is available, all prove to be very readily distinguishable. However, without this detail the shoots dealt with here are extremely difficult. Detail was not available to many of the earlier authors, and so it is quite impossible to be sure that specimens thought to be identical with one another really are. It is a case of making the best guess. For this reason few firm identifications are made, but comparable specimens are cited. Sometimes one specimen is comparable with more than one shoot; in these cases the reference appears twice.

Of the shoots confused with *Araucaria crassa*, one proves now to be another Tertiary species, of *Athrotaxis* Don, leaving a rather heterogeneous group of Mesozoic shoots. These Mesozoic species fall into the large *Brachyphyllum* Brongniart and *Pagiophyllum* Heer group of conifers. One is placed provisionally in *Pagiophyllum*, but the others are placed in a new genus. The reasons for this step are three: none of the shoots involved would fit comfortably into *Brachyphyllum* or *Pagiophyllum* as recently defined (Kendall 1947, 1948, Wesley 1956): to classify them into *Brachyphyllum* and *Pagiophyllum* would separate in an inconvenient way shoots that are very similar (*Allocladus milneanus* and *Al. cribbii*): in my view *Brachyphyllum* and *Pagiophyllum* are already too diverse for ease, and to add more badly fitting species would not make for convenience.

As regards the affinities of the Southern conifers considered here, nothing definite can be said. Florin (1940, 1963), having very imperfect evidence, considered they were araucarians. This may well prove to be so, but on present evidence they cannot be securely classified.

DESCRIPTIONS

Family Araucariaceae

Araucaria crassa (Tenison Woods) com. nov.
Pl. 1 H, Figs. 1A; 2A, C; 3B-E, H; 4A, B.

1883 *Brachyphyllum australe* var. or n.s. *crassum* Tenison Woods, p. 159-160, pl. 5. Type specimen described.

1892 *Brachyphyllum crassum* Tenison Woods in part: Jack and Etheridge, p. 385. Tenison Wood's description quoted, figs. on pls. 17 and 18 are distinct.

1917 *Brachyphyllum crassum* Walkom non Tenison Woods, p. 25. Tenison Wood's description quoted but applied to pl. 9 fig. I, which is distinct.

Holotype: No. 137 Macleay Museum, University of Sydney; Fig. 1A.

Age: Probably Tertiary from the Booval Group, Queensland. Locality unknown.

Diagnosis emended: Shoots with more or less pinnate branching of the penultimate branches; ultimate branches at least 11 cms. long and 0.5-0.75 cms. thick, curved (possibly pendulous or curved upwards in life). Shoots covered with leaves of one sort, spirally arranged, four visible in one turn of the spiral, close set and imbricated; 3-4.5 mms. long and the same or slightly less in greatest width. Leaves arising from a rhomboidal, only slightly decurrent cushion, upper margin of cushion nearly horizontal, leaves thick 2-2.5 mms. at base, free parts of leaf directed forward usually strongly curved inwards but rarely tightly appressed: lower surface more or less strongly keeled, upper surface slightly keeled, apex obtuse, margins sharp, but not scarious or scalloped. Leaf triangular, near base margin showing ear-like projections.

Leaf (in all probability) supplied by two (or three) vascular bundles, derived by branching in the cortex of a single trace.

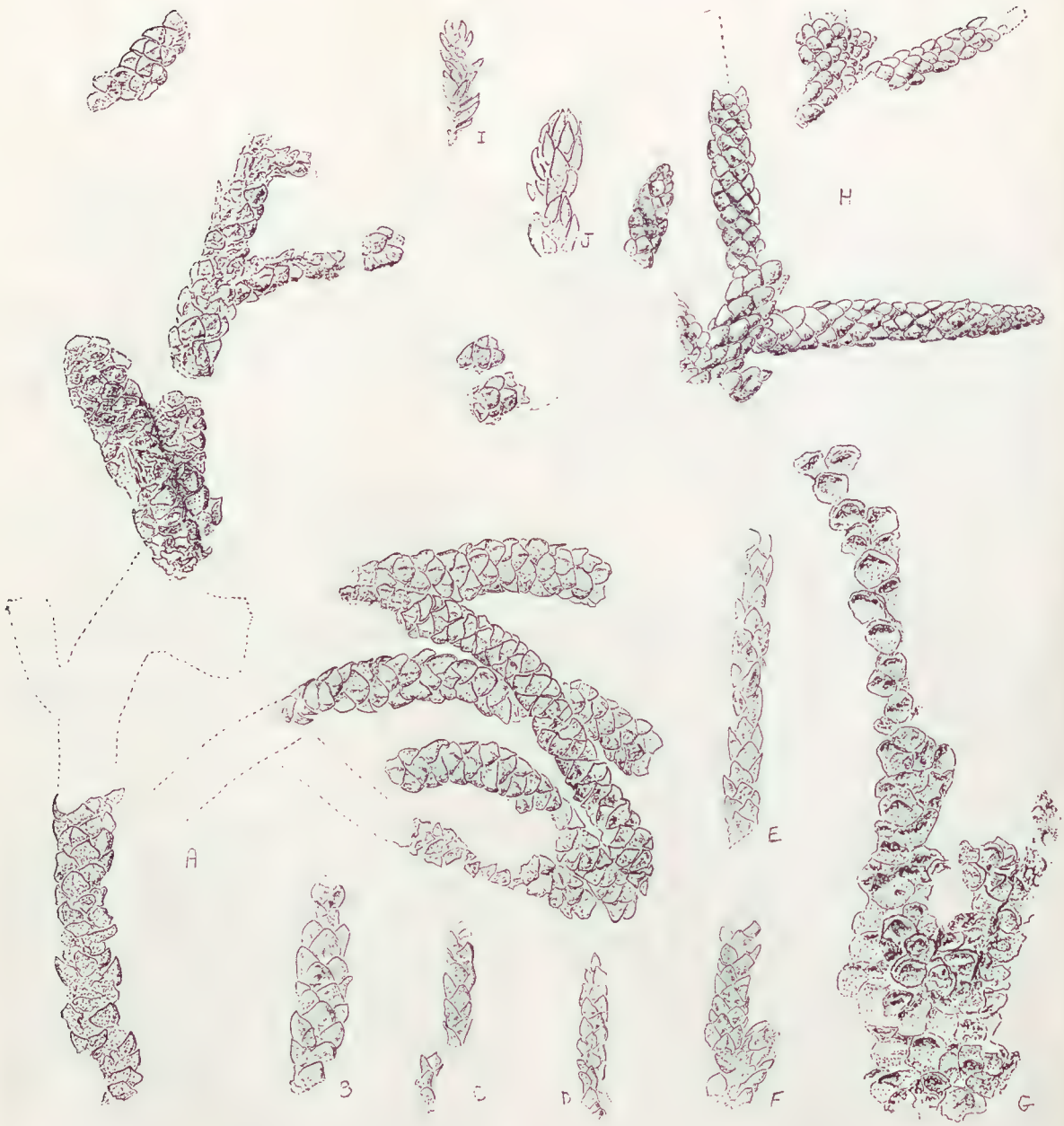


FIG. 1.—*Araucaria crassa* A; *Allocladus cribbii*, B-F; *Pagiophyllum feistmanteli*, G; *Athrotaxis tasmanica*, H; *Al. milncanus* I, J. A-I, Shoots, showing forming of branching and general appearance, all x 1. A, H, I, MacLeay Museum, 137, 41; B-F; Univ. Queensland F5075-50759; G, H, Queensland Geol. Survey, 705 and 711.

Cuticle of different thickness on two sides, below about 7μ above about 3μ. Leaf amphistomatic, on lower surface stomata grouped in two areas flanking a central "midrib", devoid, or almost devoid, of stomata, the areas reaching about to leaf apex; on upper surface stomata at least 50% more numerous, lying in similar areas flanking the "midrib". On both surfaces stomata set more or less regularly in long rows, running from leaf base to within 3-5 cells of the margin: orientation of stomatal pore irregular in the rows. Epidermal cells away from stomata more or less rectangular, in rows, becoming irregular at leaf base.

Epidermal cell outlines thick, 8-12μ, straight, or showing sinuous projections down the anticlinal epidermal cell walls, surface generally smooth, rarely ornamented with low but hollow papillae about 30μ across, papillae seen on both surfaces, near "midrib" only. Cells about 60μ x 50μ. Stomata dicyclic, on lower leaf surface normally separated by one or more epidermal cells, on upper surface adjacent stomata in the rows either sharing an encircling cell, or (about as often) having the encircling cells in contact, but only very rarely encircling cell missing. Guard cells sunken in a pit, concave (as seen from above), sides of pit formed by subsidiary cells, either vertical or overhanging, but subsidiary cells' dorsal surface more or less flat, and not papillate. Subsidiary and encircling cells together forming further pit, with sloping or vertical sides, encircling cells rarely overlapping mouth of pit. Wall between subsidiary and encircling cells heavily cutinised. Hypodermis not cutinised. Stomatal rows not sunken.

Description and Discussion: The material examined consists of Tenison-Woods' Type, shown in Fig. 1A. The specimen is now less complete than when first figured. It is not much compressed. The largest shoots show the pinnate sort of branching seen in *Araucaria* Juss. sect. Eutacta Endl. From the curving of the ultimate branchlets it seems likely, as from their size relative to the penultimate shoot, that they were pendulous, though they may have curved up, as in *A. excelsa* (Lamb.) R. Br. ex Ait. It is not quite true that the ultimate branches are the same thickness as the penultimate, and they do taper slightly (about 1 mm. in 10 cms.).

The leaves are all of the same sort, varying only in size, and degree to which they are appressed (Figs. 2A, C). When they stand out, the leaf base is seen and here too the keel on the upper surface of the leaf can be seen. Wherever the presentation allows it, a keel can be seen on the lower leaf surface, and I can find no case where it has been obliterated by pressure (Jack and Etheridge, 1892, p. 385), and in fact the shoot is only compressed to about half its original thickness, supposing it to have been round.

In one shoot, some leaves were broken in such a way that the leaf base was seen, more or less in tangential longitudinal section (the earlier authors noticed this). The clearest is shown in Fig. 2A. In the centre of the broken surface there is a more or less triangular area, not flat, but sloping so that its base lies deeper into the cortex than its top. Over part of this central area there are striae, about 50μ apart (shown diagramatically by vertical lines), forming a Y shaped pattern. There is no proof (such as pitting) that these striae are tracheid walls, but they are of the right size and in the right position for the leaf traces, which in the living species of *Araucaria* sect. Autacta emerge as a single trace from the stem stele, then divide in the outer cortex or leaf base into two or three (Fig. 6E *A. cunninghamii* Ait.). In *A. crassa* it is not clear whether there are two or three traces, but it is clear that, if these marks are tracheids, there were at least two traces in the leaf.

The cuticle is not well preserved, and brittle. The fossil is covered with a layer of mud that clings to it firmly, and large silica grains, which may have formed on the plant, locally destroying the cuticle in the process (Pl. 1 H). The pieces for maceration were first cleaned in HF. The distribution of stomata, as put together from several pieces is shown in Figs. 3 B, C, and in general, it is extremely like a living *Araucaria* (Florin 1931). The stomatal rows run vertically, so that they would impinge on the margin; they stop short, however some five cells away from the margin. The margin itself is shown in Fig. 3D and Pl. 1H, and, as in *A. cunninghamii*, appears to have been thin, (also showing ear-like projections at the base, Fig. 6F), but is definitely not scarious.

The stomatal details are given in Figs. 3H, 4B. For the most part the stomata were sunken in a pit formed by the subsidiary cells, overtopped by but rarely, overhung by, the encircling cells; there is variation however, the stomata on the upper leaf surface being rather less overhung (Fig. 3H). The cell outlines are shown in Fig. 3E, a leaf base, where compression presents them partly in section. The sinuous downward extensions are seen in *A. cunninghamii* (and others), but are larger in the living species, making the whole outlines sinuous.

Comparisons. The nomenclature of *A. crassa* is badly confused. This arises from two circumstances: the species was thought to be Triassic (or at least lower Mesozoic, a mistake heightened by the original rather misleading comparison with *Brachyphyllum mammillare* Brgt.), so it was left out of account in discussions of Tertiary species of *Araucaria*: and even more, several authors (e.g. Walkom 1917) quote the original description, mistakes and all, and apply it to specimens to which it does not fit. The Jurassic specimens to which the name *B. crassum* was applied are readily distinguishable.

In addition, the combination *Brachyphyllum crassum* was proposed in 1883 both by Tenison Woods and Lesquereux (see Seward 1919, pp. 324-325), however, contrary to Seward's statement, Tenison Woods did figure his Type, it is in his pl. 5. Lesquereux did not publish figures till 1891, and his material became entangled with another American species called originally *B. macrocarpum* Hollick and Jeffrey. As regards the Australian material, the confusion over the American species is immaterial: Tenison Woods' name was validly published (originally as a variety) and has priority, while the transference of his species to *Araucaria* avoids the difficulty caused by one binomial being given to two different species.

At every available point the specimen agrees with species of *Araucaria* sect. Eutacta. The branching, including possibly pendulous habit sometimes seen

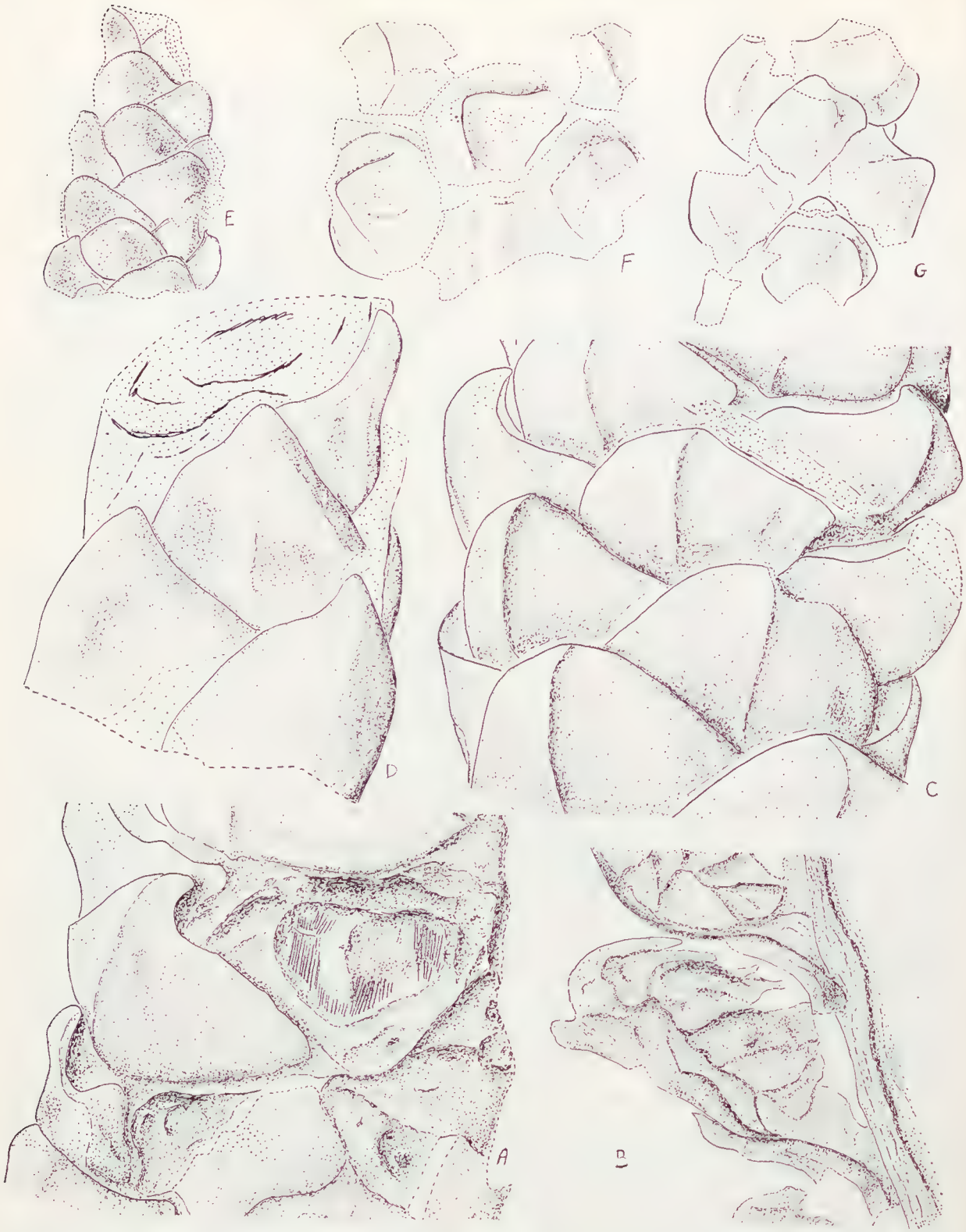


FIG. 2.—*Araucaria crassa* A, C; *Conites tenison-woodsii* B; *Athrotaxis tasmanica* D, E; *Pagiophyllum feistmanteli*, F, G. A. Part of a shoot showing broken leaves and traces within the leaf base believed to be of tracheids (vertical lines). x 7, MacLeay Museum 137. C-G. Parts of shoots to show differences in leaf shape, all x 7. C, MacLeay Museum 137; D-G, Queensland Geol. Survey, 705, 753 and 711. B. A unit of structure showing its double nature, and adaxial objects, possibly seeds. x 7. MacLeay Mus. 102.

in *A. excelsa* and more often in *A. columnaris* Hook., the sort of leaf, the cuticle and (in all probability) the leaf vascular supply, can all be matched. There are some difficulties; the leaves are shorter and wider than is common, but the living *A. bernieri* Bucholtz (1949) has leaves of similar size and shape (see Table I in Cookson and Duigan 1952). *A. biramulata* Bucholtz (*loc cit.*) is also similar, as Selling (1950 p. 557) remarks. The cell outlines are straight, only rarely showing sinuous projections, but the projections are of the same sort as in several living species, and the fossil *A. lignitica* Cookson and Duigan has cell outlines looking very similar, though sometimes obscurely pitted. The stomata may be overhung more than is usual, but again *A. lignitica* (a species known from cones as well as shoots) provides a parallel. These difficulties are fairly small, the living species seem to show the same sort of variation among themselves (Florin 1931, p. 232, Cookson and Duigan, 1952, p. 422), and there seems no good reason for keeping *A. crassa* out of *Araucaria*. In gross form (as in cuticle) it is like *A. bernieri* or *A. montana* Bgt. and Gris, but since it does not correspond exactly with any living species, it is worthy of specific rank.

Among fossil *Araucaria* species, comparison is close with *A. fletcheri* Selling (1950). This species, whose holotype I have examined, has leaves of similar size, 2-4 mm. long and 3 mm. wide, but which stand out from the stem more than the leaves of *A. crassa*, though the difference is not large, and might have been caused by different preservation. The two species are separable on their stomatal distribution. Whereas *A. crassa* shows stomata more or less all over the lower leaf surface, except for a narrow and somewhat ill defined midrib. *A. fletcheri* shows them only at the leaf base and in two small groups. On Cookson and Duigan's (1952) fig. 2, *A. crassa* falls with *A. montana* or *A. bernieri* (type A1 or A2) while *A.* fletcheri goes with A. columnaris (type C), as Selling (*loc. cit.*) indicated. On the upper leaf surface, the stomata are much more closely packed in *A. fletcheri* than in *A. crassa*, Density H.P. field 18:3, Stomatal Index 7:18. However, in stomatal details the two species are much alike, and also, in *A. crassa* there is wide variation in the number of stomata on the lower leaf surface, from leaves much like *A. fletcheri* to leaves showing about twice the number of stomata of the leaf shown in Pl. 1H. All these leaves come from a single shoot. Similar variation, though not so wide, is seen in such material of *A. excelsa, A. cunninghamii* and *A. columnaris* as I have had access to.

It will be best to keep *A. crassa* and *A. fletcheri* separate, but they are still decidedly similar. There do not appear to be other species with which serious confusion is likely.

I have not seen any material from the Triassic at Ipswich preserved like *A. crassa*, but do not know the flora well. On the other hand, *Athrotaxis tasmanica* (below), a Tertiary species, is preserved in the same way as *A. crassa*. Also, *A. crassa* is more like a Tertiary fossil or living species than anything known yet from the Triassic. For these reasons *A. crassa* is dated as Tertiary. It probably comes from the Booval Group (Hill and Denmead) 1960), but the locality is unknown.

Family TAXODIACEAE

Genus **ATHROTAXIS** Don

ATHROTAXIS TASMANICA nom. nov.

Figs. 1H; 2D, E; 3A, F, G; 6G.

1892 *Brachyphyllum crassum* Jack and Etheridge non Tenison Woods, pp. 385-386, pl. 17, figs. 11, 12 (F705); pl. 18, fig. 3. (F753), fig. 2 indeterminable. Material from Queensland.

1917 *Brachyphyllum crassum* Walkom non Tenison Woods, p. 25, pl. 9, fig. 1. Earlier material refigured.

1965 *Athrotaxis ungeri* Townrow non Halle, pp. 109-112, figs. 1 A-G and 2 A-G. Material from Tasmania

Holotype: F705 Queensland Geological Survey, see Fig. 1H.

Age: Probably Booval Group, Lower Tertiary.

Diagnosis emended. Shoots showing alternate to nearly opposite branches, coming off at various angles round main shoot. Shoots 2-5 mm. in diameter, showing more or less closely appressed, spirally arranged leaves, and rounded ends not much narrower than older parts of branch. Usually one complete leaf and parts of two or three others seen on each surface of shoot. Leaves more or less triangular, with rounded apex, about 3 mm. long and 2.5 mm. wide (extremes 4 x 3 mm. and 2.0 x 1.0 mm.) widest part about 0.75 mm. from leaf base, and leaf contracted slightly towards leaf base, contracting steadily above. Leaves thick, 1.5 mm. (compressed sideways) not keeled, showing general thick area, tapering rapidly in about 0.2 mm. to margin. Upper leaf surface flat, consisting of a portion over the midrib about 0.75 mm. long, and two flanking areas, tapering to widest part of leaf.

Cuticle on lower surface 2-5μ thick, on upper surface 1-2μ thick. Leaf amphistomatic, stomata lying on lower surface in two zones of indefinite outline, and set near leaf margin, separated by side non stomatiferous zone. On upper surface, two similar zones not reaching apex. Stomata showing no regular orientation or arrangement, many orientated longitudinally. Epidermal cells away from stomata in indistinct longitudinal rows; on lower surface cells equidimensional or wider than long, about 40μ x 35μ, on upper surface cells more or less rectangular 38μ x 20μ. Cell outlines more or less thick, up to 7μ, mostly straight but sometimes showing lateral small projections of cutin, and sometimes pierced by holes.

Stomata monocyclic (very rarely incompletely dicyclic), subsidiary cells more or less equidimensional, quite unspecialised, forming a ring of 5 (4-8) round the stomatal pit, not divisible into lateral and polar members. Guard cells feebly cutinised, sunk in a pit; pit overhung by a collar of cutin borne on the subsidiary cells. Collar 5μ-10μ wide, total width of more or less round stomatal pit 20μ-50μ.

Leaf margin scarious, formed of long finger like cutinised cells, often transversely divided, up to 0.2 mm. long, joined to one another below. Scarious margin longest near leaf apex, but extending all round leaf.

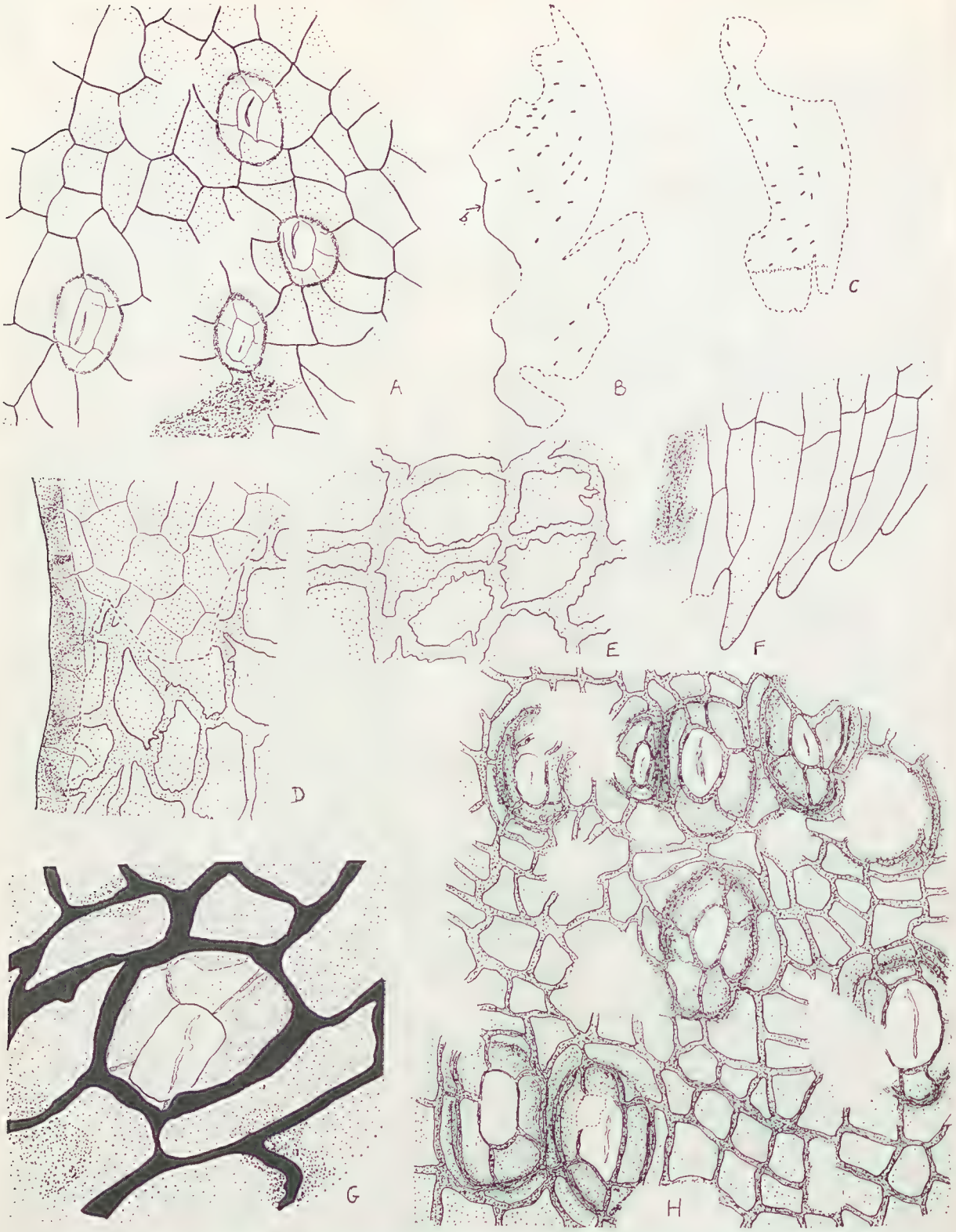


FIG. 3.—*Athrotaxis tasmanica* A, F, G; *Araucaria crassa* B-E, H. A, Part of the upper cuticle showing stomata, x 200. Queensland Geol. Survey, 705. B, C. Parts of the cuticle from the lower leaf surface, showing number and arrangement of stomata *b* = leaf base x 20. D, the leaf margin. Upper surface cuticle fine lines, x 500. MacLeay Mus. 137. E. Sinuous cell outline, x 800. F. part of leaf margin, x 200. G. A stoma. x 600. Queensland Geol. Survey, 705. H. Part of the cuticle of the upper leaf surface. Note holes left by *in situ* growth of silica. x 200. MacLeay Mus. 137.

Description: The Queensland material consists of two specimens collected many years ago, F705 from "Walloon" (a designation by itself of uncertain meaning, when used by the early collectors) and F753 from Rosewood near Ipswich, in ash beds, according to Jack and Etheridge (1892, p. 385). F.705 is covered with the muddy deposit already mentioned for *A. crassa* (p. 151), and F753 shows no cuticle but does show the external form of the leaves very plainly. Both specimens are little compressed, F753 is still nearly round in section. To obtain details from F.705, two small lengths were removed from the specimen and treated with HF; they were afterwards macerated.

F.705 is shown in Fig. 1H, where the branching consists of more or less, but not completely opposite pairs of branches, and each pair comes off at an angle of 45°-90° to the pair below. One branch is complete, it is 2.5 mms. long and tapers from 4 mm. to 2 mm., the apex being rounded. As covered by the mud the details of the leaves are entirely obscured; on removing this, the leaves are seen to lack a keel, but to be thick, and raised over the whole lower surface of the leaf, except where it thins suddenly to the markedly scarious margin (Figs. 2D, E). The leaves differ in size, but usually show a somewhat curved margin (Figs. 2D, E). In F753 the leaves are large, but what is important, show the scarious margin, even though no plant material remains. In this specimen a very faint keel can be seen in places.

The cuticle is badly preserved, and could only be obtained in small pieces, but these are numerous, and come from all over the leaf, so that though stomatal distribution (for example) cannot be determined, the details of cells, stomata and margin can be made out.

The cuticle is of two thicknesses, the thinner one presumably the upper. On both, the form of the cells is given in the diagnosis (see Figs. 3A, G; 6G).

The cell outlines are often damaged, at first sight looking sinuous, but in a few places they really are sinuous, by reason of small cutin projections, pointing partly downwards into the leaf, a feature also seen in *Athrotaxis cupressoides* Hook. The stomata are also often damaged. Figs. 2A, G, show some of the better ones, and these show the walls of the pit, appearing as a dark line, within which arises the cutin collar, showing the outlines of the subsidiary cells. The margin is shown in Fig 3F.

Comparison: The specimens differ from *A. crassa* in size, branching, leaf shape and cuticular features, and cannot be identified with it. In branching and leaf shape they agree with *Athrotaxis*, and come near to *A. cupressoides* (see Florin 1931, pl. 11, fig. 8), but differ in showing a large scarious margin (*A. cupressoides* has only a small one) and in lacking a keel to the leaves, but as already noted, this can be largely an effect of drying. In cuticle, the details of the cells and stomata agree with *Athrotaxis*.

At the specific level, the material is identified with some specimens from the Tasmanian Tertiary (Townrow 1965). The Tasmanian specimens consisted of only short lengths of shoot, but in showing a large scarious margin, and in leaf shape the two agree. The Tasmanian material had an excellent cuticle, clearly showing stomatal distribution and the Queensland material is identified with it because, though less clearly it shows the same features. There is, however, one difficulty. Sinuosities were not at first seen on the Tasmanian leaves, on re-examination a few were seen, but they are smaller than on F.705. Both sets of specimens show the unusually wide cutin collar over the stomatal pit.

Earlier (1965) I identified the Tasmanian material, though with much hesitation, with *Athrotaxis ungeri* (Halle) Florin, (Florin 1960), from the Lower Cretaceous of Patagonia, the recent revision of this species by Archangelsky (1963), not being to hand. The identification was certainly incorrect. The leaves of *A. ungeri* are smaller than of the present species. (2 mm. long 1 mm. broad) and though they have a margin (Archangelsky *loc. cit.* pp. 83-86, pl. 10, fig. 68) it may be smaller than in these specimens. Also, there are many more stomata on the lower surface on *A. tasmanica* than *A. ungeri;* and the cutin collar round each stomatal pit is absent (or very small) in *A. ungeri.*

Various other Australian fossil species of *Athrotaxis* are compared elsewhere (Townrow 1965 p. 112); in gross form *A. tasmanica* comes nearest to the living *A. cupressoides*, but in cuticle to *A. laxifolia*. No living species shows so large a scarious margin and cutin collar over the stomatal pit.

CONIFERALES INCERTAE SEDIS

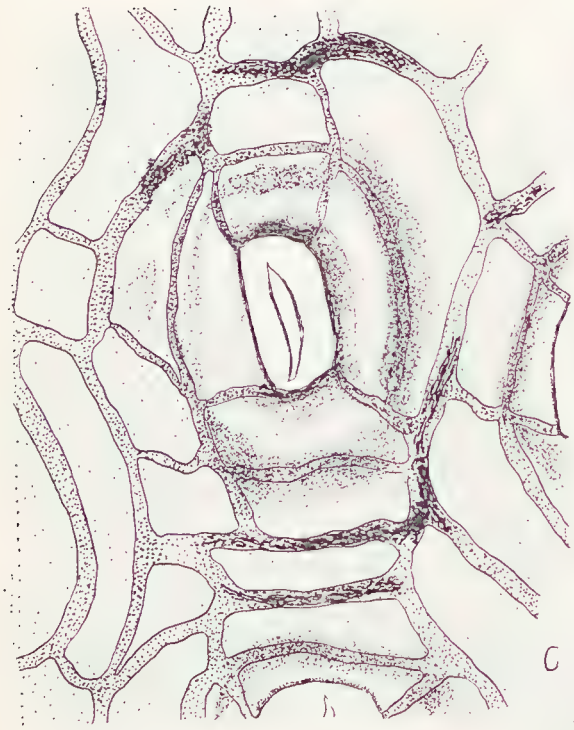
ALLOCLADUS gen. nov.

Type species *Al. rajmahalense* (Feistmantel)

Diagnosis: Conifer shoots, showing sparse irregular branching of the penultimate shoot system, and similar leaves all over. Leaves close set, spirally arranged, phyllotaxis probably 2/5 and/or 3/8. Leaves arising from a decurrent base, overlapping the next leaf above, and with free parts directed forward, parallel with, or nearly parallel with, the shoot long axis. Length of the free part of the leaf about as great as or greater than its width.

Leaves more or less triangular in outline, with apex acute, 2-8 mm long, with angular margin showing scarious projections. Leaves thick, strongly convex on lower surface but more or less strongly concave on upper surface. Leave base cushions concealed, probably more or less rhomboidal. (Venation unknown).

Leaf epistomatic, (rarely in one species with a few stomata on the lower leaf surface). Stomata either set in two zones, near the leaf margins, coalescing at leaf apex, or in one mass over central part of leaf upper surface, obscurely separating into two zones towards leaf base. In zones stomata either scattered, or showing a weak tendency to be in vague longitudinal rows; orientation of guard cells various. Ordinary epidermal cells square or slightly elongated, outside stomatal zones lying in rows converging on the apex, sometimes papillate, Hypodermis sometimes cutinised, consisting of narrow strongly elongated cells. Cuticle thick (5μ or more).



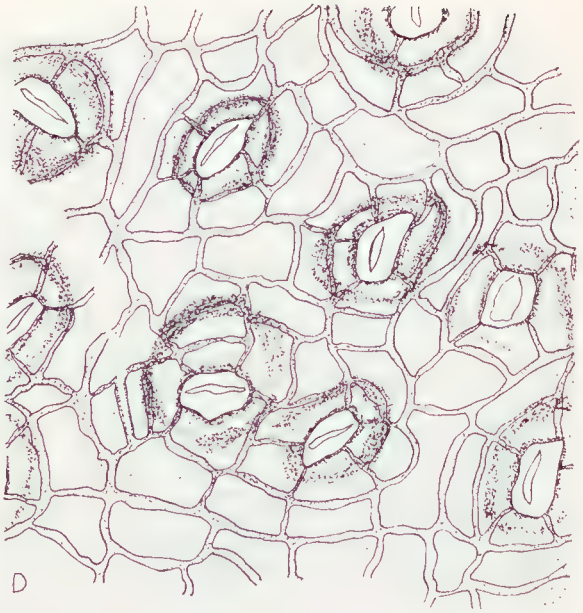


FIG. 4.—*Araucaria crassa* A, B; *Allocladus cribbii*, C. D. A. Stoma near the leaf base, and cells with papillae. x 150. B. A stoma, from upper leaf surface, x 600 MacLeay Museum 137. C. A stoma from about middle of the leaf x 600. D. Part of the upper leaf surface cuticle, x 200. Queensland Univ. F50756, F50758.

Stomatal zones not sunken, but individual stomata sunken, and usually dicyclic, 3-6 subsidiary cells forming a ring. Wall of pit formed by subsidiary and encircling cells together, and encircling cells sometimes overhanging the mouth of the pit. Dorsal surface of subsidiary cells more or less flat, bearing only minute cutin thickening overhanging the guard cells, or such thickening absent. Adjacent stomata usually separated by an ordinary epidermal cell, but sometimes encirling cells in contact, very rarely encircling cell shared between adjacent stomata.

Discussion: The shoots now segregated into *Allocladus* shows the general form of some species of *Araucaria*, sect. *Eutacta*, especially of *A. cunninghamii*, or of *Athrotaxis*, especially *A. sellaginoides*, and of some shoots referred to the form genus *Pagiopyhllum* Heer. They have more or less short leaves, the same over the whole shoot (as far as known), forwardly directed, and emerging all round the shoot (pl. 1B, D, Figs. 1, 7, 10). Only one specimen of the material available to me shows the branching pattern, (cf. the specimen of Walkom's (1921, p. 13, fig. 2) if correctly identified), and branching would seem to have been sparse and irregular. It is possible that the specimens consist of ultimate shoots, shed intact (again as in *A. cunninghamii*) but there is no evidence that this is so.

The form of the leaf base is uncertain, because each leaf covers the base of the one above (e.g. Fig. 7A, B), but in the lower parts of the shoot of *Al. milneanus*, the leaves spread out, and the one shown in Fig. 7B, is near the leaf base, which was probably of the normal decurrent sort.

The lower surface of the leaf shows no signs of a keel, but in *Al. milneanus* there are two angles at the leaf base (Fig. 7B), suggesting that on this surface the leaf was thick, rounded and convex, and either thinned suddenly towards the margins, or (*Al. cribbii*) was rounded, thinning more gradually towards the margins. The upper leaf surface was concave especially in *Al. cribbii*, and this is interpreted to mean that in life the upper leaf surface was concave, and, having impressed its shape onto the mud during fossilisation, has collapsed on to the mould so formed (Walton 1936).

The cuticles of all species are thick, and easily prepared. It was surprising to find that the leaves showed stomata only on the upper surface, and preparations were made of whole leaves, and large pieces of known orientation (on the basis of the leaf shape just set out) to confirm this. However, in one species *Al rajmahlensa*, some leaves, probably less than a tenth, show a few stomata on the lower leaf surface (p. 159). This exception, being rather minute, is ignored in the following discussion. The stomata are regularly dicyclic, and their arrangement has already been given in the diagnosis (see Figs. 4, 5, 11). As interpreted, the whole subsidiary cell ring is sunken, and the wall (or most of it) of the stomatal pit is formed by the encircling cells. The evidence for this is best seen in *Al. milneanus*, and is as follows. Viewed from the inner surface focussing shows first the guard cells with the stomatal aperture, and then, at only a slightly different level, the whole of the subsidiary cell surface. Finally, cell outlines continuous with those of the subsidiary cells, can be seen, and these pass *over* a thick mass of cutin representing the lips of the stomatal pit, being continuous with the outlines of the encircling cells as seen on the general surface of the cuticle (Figs. 5C, G). The whole appearance comes close to that seen in *Cycas revoluta* L. and presumably is to be interpreted the same way.

The hypodermis, where present, underlies the encircling cells, but, so far as can be seen, the dorsal wall of the subsidiary cells, which they share with the encircling cells, is not specially heavily cutinised—indeed it is often hard to make out. (Fig. 5A).

The margin of the leaf is modified. In *Al. cribbii* (in which no hypodermis can be seen) groups of epidermal cells turn and run out into short finger like processes along the edge of the leaf, similar to those seen in *Microstrobos*, and many other conifers. In *Al. milneanus* these scallopings are up to 1 mm. high, and consist of whole groups of epidermal cells, with their hypodermal cells, which turn outwards to form almost shovel-like projections (Fig. 5B). *Al. rajmahalense* is intermediate.

Comparisons: Twigs of *Allocladus* look rather like those of certain species of *Araucaria* or *Dacrydium* Sol. or *Athrotaxis*, but the difference in cuticle precludes referring *Allocladus* to any of those genera. It is more difficult to distinguish from *Brachyphyllum* and *Pagiophyllum* (Kendall 1947, 1948, Wesley 1956), as they are defined broadly, separated arbitrarily from one another, and probably artificial. *Allocladus* would however, make exceptional species, for no *Brachyphyllum* or *Pagiophyllum* is epistomatic, none have a scalloped margin, and in most (not all) the stomata run in rather well involved longitudinal rows.

It is difficult to discuss the possible relationship of *Allocladus* with *Brachyphyllum* and *Pagiophyllum*, since *Brachyphyllum* contains definite Araucariaceae (*B. mammillae*, see Kendall 1919a), and at least one species, *B. expansum* definitely not Araucarian (Kendall 1950). Perhaps it is fair to say that there are no features which particularly suggest relationship between the genera.

Cheirolepidium muensteri (Schenck) Takhtajan, (Florin 1944, (further references given), Harris 1957, Lewarne and Pallot 1957, Woods 1961, Halloner 1962) consists of shoots and cones, but only the shoots will be considered here since the *Allocladus* cone is unknown. The leaves vary considerably in length, but are generally from 2 mm.-5 mm. long and 1.25-3 mm. wide, and more or less appressed to the stem. They show a concave upper surface and, as noticed by Lewarne and Pallot, may show a scarious margin. The margin even when scarious is unscalloped. The cuticle is thick, (5μ or more) and shows stomata in irregular files on both surfaces and rows of little elongated cells. The cell outlines are straight. The stomata are generally described as monocyclic, but some at least are, as some authors have noticed, incompletely dicyclic (e.g. Lewarne and Pallot 1957 fig. 1B). Papillae have not been reported, though the subsidiary cell surface may be thickened. A hypodermis is sometimes to be seen.

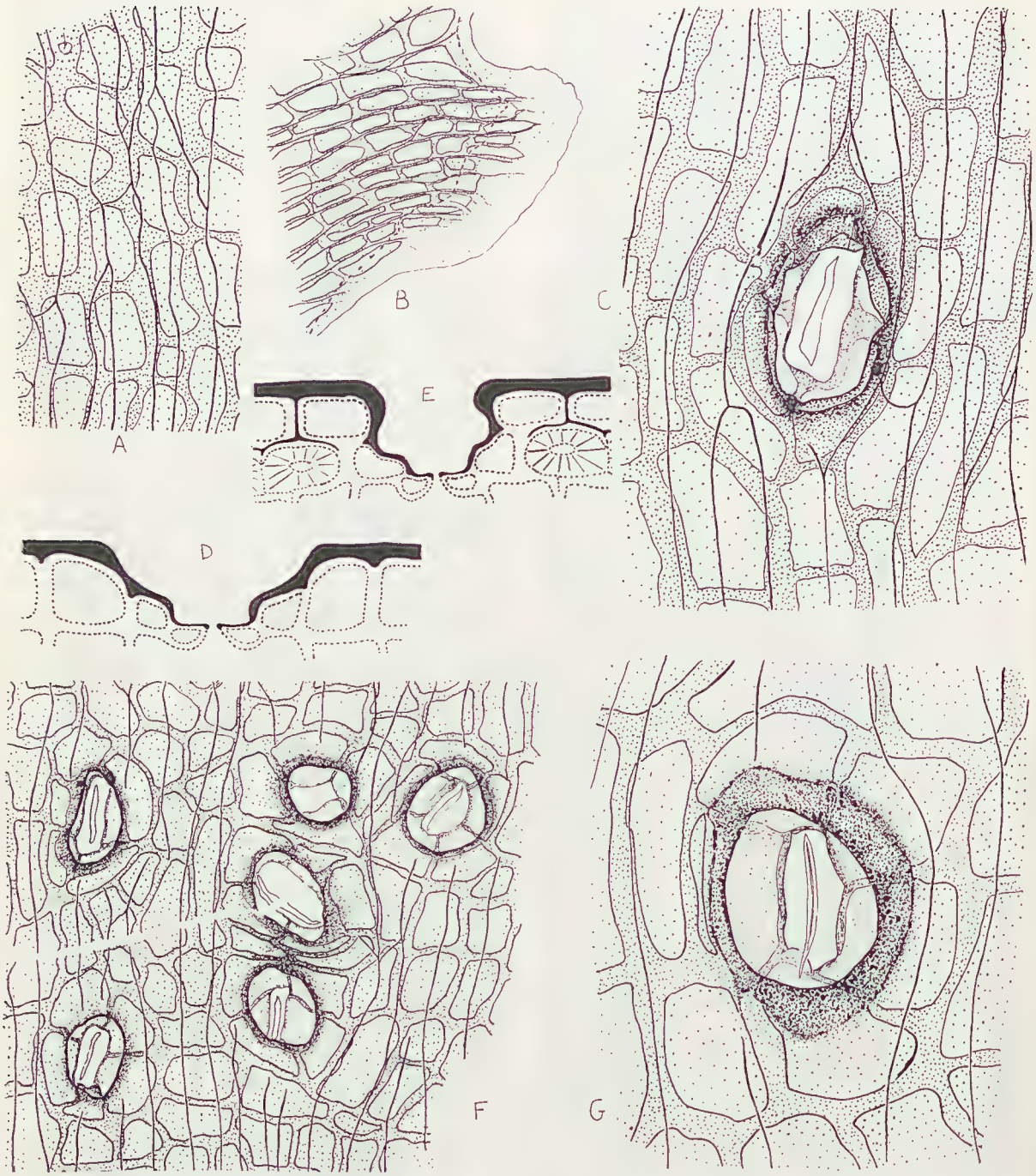


FIG. 5.—*Allocladus milneanus* A-C, E-G; *Al. cribbii* D. A. Cells, epidermal and hypodermal, of the lower leaf surface x 200. B. A marginal projection, with its epidermal and hypodermal cells. x 100. C, G. Stomata, seen from outside in (C) and from inside out (G), to show forms of the pit. x 600. F. Cells of the upper leaf surface x 200. All MacLeay Mus. 41. D, E, Reconstructed transverse section through a stoma. x ca. 600.

Thanks to the kindness of Dr. W. G. Challoner (University College London,) I have been able to examine material of *C. muensteri* from Schnaittach. In addition to the points mentioned above, the cuticle of *C. muensteri* does rather rarely show low papillae to a point at which it compares with *Al. cribbii*. Also, in at least half of the stomata examined a difference in level can be detected between the subsidiary cells and their neighbours (cf. Wood 1962, fig. 2). The possibility was considered that this might be merely a compression fold, but first, it is found in parts of the leaf compressed vertically, i.e. where no other folding exists, and second it extends all the way round the stomatal apparatus, whereas a compression fold would be expected on one side only.

Cheirolepidium and *Allocladus* show some very interesting similarities. The leaf outline, and shape in section, is similar or the same, the branching is irregular, not pinnate, the cuticle is thick, the cells not much elongated, and the stomata variously orientated. The cells of *Cheirolepidium* may rarely be papillate. *Cheirolepidium* may have a scarious margin. *Al. milneana* has a cutinised hypodermis, as *Cheirolepidium* sometimes has.

They differ, however, in that (1) *Allocladus* is epistomatic, but *Cheirolepidium* amphistomatic, (ii) *Allocladus* has a scalloped leaf margin but *Cheirolepidium* does not, (iii) *Allocladus* has regularly dicyclic stomata, with the subsidiary cells sunken, but *Cheirolepidium* is only irregularly dicyclic or monocyclic with only slightly sunken subsidiary cells. These differences are enough to make a useful generic separation between the two.

Haiburnia Harris (1952), Florin (1958) has a leaf crescentic in section like *Allocladus*, and with a scarious margin, and in *H. blackii* Harris the stomata are dicyclic. However, the leaves are amphistomatic, though with more stomata on the upper surface in *H. blackii*, the stomata are scattered all over the leaf, and the stomatal details differ (see Harris 1952, figs. 3B, D). *Haiburnia* definitely has only one vein in its leaves.

ALLOCLADUS RAJMAHALENSE (Feistmantel) com. nov.

Pl. 1D. Figs. 8C, D, E; 10; 11A-D.

1877 *Echinostrobus rajmahalense* Feistmantel, p. 90, pl. 65, figs. 3, 3a. Small branching shoot, from "Bindabrum, Amrapora, Burio, &c."

1928 *Brachyphyllum mammilare* Sahni non Brongniart, p. 18, pl. 2, figs. 19, 20 only. Feistmantel's specimen refigured.

Comparable Specimens. Oldham and Morris 1863, pl. 32, fig. 8 (very obscure fragments): Feistmantel 1887, pl. 42, fig. 2; 1879, pl. 19, figs. 2, 2a; 1879, pl. 12, figs. 2, 2a, *and* the whole list given under *Al. cribbii*.

Holotype: Feistmantel 1877, pl. 65, fig. 3. 283. 4/532, Geol Survey, India.

Locality: Bindarum, Rajmahal Hills; Middle Jurassic.

Diagnosis emended. Leaves very closely appressed, so whole shoot appearing circular in section and about 3 mm. in diameter. Leaves about 2 mm. long and same or slightly less at widest point seen, triangular, of obtuse apex, making an angle of less than 20° to axis of shoot, about 1.5 mm. thick at base (when compressed laterally). Leaf under surfaces somewhat convex, not keeled and without angles towards leaf margin, upper surface somewhat concave. Branching irregular.

Cuticle of markedly different thickness on two sides of the leaf, on lower side about 5μ, on upper 1-2μ. Stomata probably in two vague zones towards leaf base, zones coalescing towards leaf apex; within zones stomata more or less longitudinally orientated, more or less in rows, but many out of their rows. A very few stomata rarely present on lower leaf surface near leaf margin. Stomata irregularly dicyclic, usually with encircling cells in contact but not shared. Ordinary epidermal cells more or less rectangular on both leaf surfaces; on lower cells about 50μ x 40μ, on upper more elongated, about 60μ x 40μ. Cells papillate at leaf base on lower cuticle only, papillae as for *Al. cribbii*. Cell outlines thin, about 3μ sometimes bordered.

Stomata sunken in a pit, walls formed wholly or mainly by subsidiary cells, encircling cells not overhanging pit. Subsidiary cells numbering 3-6.

Margin scarious, scalloped (as *Al. cribbii*) only at leaf base, cutinised hypodermis not seen.

Description and Discussion. The material consists of one large shoot and five smaller pieces collected by Mr. R. Gould at I at Tannymorel Colliery, and it is well preserved. This is the only species in which the branching pattern is seen clearly, and it is irregular (Pl. 1D). The branches come off at various angles in all three planes, and it often happens that both parent shoot and branch are about the same size (dichotomous of Feistmantel 1877). The shoot apex is shown in Fig. 8C; and one short branch tapered from 2 mm. diameter to 1.5 mm. in 5 mm.

The leaves are closely appressed, more so even than *A. cribbi* (Figs. 8C-E), and overlap one another, so that the leaf base is not seen. One and part of two other leaves, or two half leaves are seen in one side of the spiral. The upper (adaxial) leaf surface is not well seen, but in one or two places (Fig. 8E), where matrix has got between the leaves the whole leaf is convex towards the observer, suggesting that the leaf was concave above (see below *Al. cribbii*). Parts of shoots, when macerated and then dissected apart also show a more or less concave upper surface. The lower (abaxial) surface is rounded and, usually (Figs. 8C, D), not very convex.

It proved very difficult to obtain good cuticle preparations of the upper leaf surface, and I have not seen a leaf in which it was complete. Fig. 4B shows one in which a good deal of the cuticle remains, and it appears from it that the upper cuticle extended as two more or less narrow strips about to the widest part of the leaf, but was probably not extensive at the leaf apex. The stomata are often in one mass at the leaf apex, but another specimen (Fig. 4B) shows some near the leaf margin, but towards the midrib there are somewhat elongated cells but no stomata. In two leaves, out of some 15 macerated, there was a group of 3 or 4 stomata, extending laterally from the leaf margin

FIG. 6.—*Cycas revoluta* A, B; *Allocladus milneanus* C; *Pagiophyllum feistmanteli* D; *Araucaria cunninghamii* E, F; *Athrotaxis tasmanica*, G. A. Stoma in surface view, viewed from inside out x 600. B. Section of two stomata. x 400. C, D., Part of the upper (C) or lower (D) surface of a leaf, showing number and arrangement of stomata, x 20. MacLeay Mus. 41: Queensland Geo. Surv. 711. E. Section through leaf bases, vascular tissue black, x 15. F. Part of a shoot, lower leaves broken off to show vascular tissue in one (Cf. Fig. 2A) x 7. G. Cell outlines from the lower leaf surface cuticle. x 800. Queensland Geol. Surv. 705.

towards the midrib, set on thin cuticle, passing smoothly into thick cuticle like that of most of the lower leaf surface (Fig. 4C). It appears therefore that in this species there were, somewhat rarely, a very few (perhaps 8 or 10) stomata on the lower surface of certain leaves, at the base. However, at least 8 leaves definitely had no stomata on the lower surface. The whole leaf, on this information is reconstructed like the leaf of *Diselma archeri* Hook. (See Florin 1931, pl. 45, fig. 5), only in *Diselma* the leaf is regularly amphistomatic. The cells and stomata are shown in Figs. 10, 11. The stomata are often, but not always, dicyclic, and when massed closely together, the subsidiary cells may be in contact. When dicyclic there is a band of darkly staining cutin adjacent to the outline between the subsidiary and encircling cell (Fig. 11A, C). This is interpreted as the compressed wall of the stomatal pit, and if the stoma is monocyclic, it lies on the subsidiary cells (Fig. 11D). The stomatal pit is therefore supposed to be formed partly by subsidiary and encircling cells together, or sometimes by the subsidiary cells only. The stomata of *Al. rajmahalense* are rather more often longitudinally orientated than in the other species.

As with many identifications, it is impossible to have any assurance that Feistmantel's specimens (1877 pl. 65, fig. 3) and mine are identical, while Sahni (1928 pl. 2, figs. 19, 20) provides a new photograph but no more information than Feistmantel. The shoots agree in manner of branching, in size, and in leaf shape and size, except only that some leaves on Feistmantel's shoot may have a slightly more acute tip than is normal in mine, though they can be matched. These similarities are held to justify identification. The new information makes it plain that this species is not identical with *Brachyphyllum mammillare* (see Kendall 1947, 1950), as Sahni thought, which differs in having many stomata on the lower leaf surface. The stomatal distribution indeed separates *Al. rajmahalense* from other *Brachyphyllum* species known in detail (e.g. Kendall *loc. cit.*, Wesley 1956, Archangelsky 1963). It is, I think, most improbable that *Al. rajmahalense* is identical with the younger shoots from Jabalpur called by Feistmantel and Sahni *Brachyphyllum mammillare* (almost certainly incorrectly, Florin 1940), but these shoots are not yet known in detail to settle the matter.

Brachyphyllum spiroxylon Bose (1952) is much like *Al. rajmahalense* in general form, but differs in its epidermis having more or less equally amphistomatic leaves, with scattered stomata (scarcely organised into lines or rows) hardly sunken at all and only irregularly dicyclic. It is still possible (in my view) that Feistmantel's specimen is really to be identified with *B. spiroxylon*, though Bose rejects this.

Al. rajmahalense is a Middle Jurassic species (Krishnan 1954, de Jersey and Paten 1965).

ALLOCLADUS MILNEANUS (Tenison Woods) com. nov.

Pl. 1A, G; Figs. 1I, J, 5, (not 5D), 6C, 7B.

1883 *Walchia milneana* Tenison Woods, P. 163-164, pl. 2, fig. 3 and pl. 6, fig. 7. (The supposed cone is excluded).

From the ? Lower Jurassic of Ballimore, New South Wales.

1921 *Pagiophyllum peregrinum* Walkon, non Lindley and Hutton, pp. 15-16, pl. 3, fig. 2. Talbragar Fish Bed, Lower Jurassic.

1928 ? *Brachyphyllum expansum* Sahni non Sternberg, pl. 2, figs. 28, 29, Golapilli, near Ellore, ? Lower Jurassic.

Comparable specimens. Feistmantel 1887, pl. 44, figs. 5, 5a; 1877a, pl. 8, fig. 8; 1879, pl. 16, fig. 10; Halle, 1913, pl. 8, figs. 15, 16; Sahni, 1928, pl. 2, figs. 21, 22; Feruglio, 1934, pp. 20-21, pl. 1, figs. 1-6; Jones and de Jersey, 1947a, figs. 15-17.

Holotype. McLeay Museum, No. 136, Pl. 1A.

Locality. Talbragar River near Ballimore (spelt Ballinore) ? Lower Jurassic.

Diagnosis emended. Leaves appressed or spreading about 8 mm. long (6-9 mms), widest about at junction of upper surface to the stem, about 3 mms. wide (2-4 mms.) at widest. Leaves directed forwards, falcate, making angle of up to 30° with shoot axis, 2.5-5 mms. thick (measured when compressed laterally). Leaf under surface not keeled, showing towards base two angles near the margin, upper surface only slightly concave. Leaf apex acute. (Branching pattern unknown).

Cuticle fairly thick (5μ), of about same thickness on each surface. Stomata in two zones, coalescing near leaf apex, and lying in short rows of 2-5, rows more or less longitudinal, but up to half stomata not in a row. Stomata strictly dicyclic, encircling cells of adjacent stomata almost never in contact. Ordinary epidermal cells about square or slightly elongated, 50μ x 30μ, not papillate, walls straight and indistinct, but thick, about 8μ. Stomata deeply sunken in a pit (depth not known), 3-6 subsidiary and encircling cells. Encirling cells forming much (if not most) of wall pit, and overhanging its upper edge.

Margins showing shovel-like scallopings, about 0.1 mm. high and 0.5 mms. apart; scallopings containing both epidermal and hypodermal tissue. Hypodermis cutinised.

Description and Discussion. The material available to me consists of the single block figured by Tenison Woods (1883), pl. 2, fig. 3. This shows fragments of three shoots, the longest of which (Pl. 1A) is taken as the holotype.

The angle which the leaves make with the stem varies: at the apex (Fig. 1J) they are appressed, though still falcate, on the larger (? older) shoots (Pl. 1A) they are more widely spread out, and the interstices between them filled with mud. The leaf base is not clearly seen, because of the way in which the leaves overlap one another, but I suspect that in the leaves in Fig. 7B we are near it, and it appears to have been of the normal decurrent sort.

The cuticle is easily prepared. Even after staining the wide cell outlines are somewhat indistinct, but the hypodermis (which must have been very strongly cutinised) shows up most clearly. In this species, as with the others, one was surprised to find that the leaves were epistomatic, and tried to check on this by observing the leaves throughout maceration, and by macerating leaves known way up. However, it seems clear that the leaves are epistomatic (see Pl. 1G, Fig. 5F).

FIG. 7.—*Allocladus cribbii* A; *Al. milneanus* B; *Pagiophyllum feistmanteli* C, D. A. B. Parts of shoots to show form, especially of margins. x 7. Univ. Queensland F50756 and MacLeay Mus. 41. C, D. Parts of shoots with large leaves and leaves of medium size, showing variation in form of the free part of the leaf. x 7. Univ. Queensland, F50769.

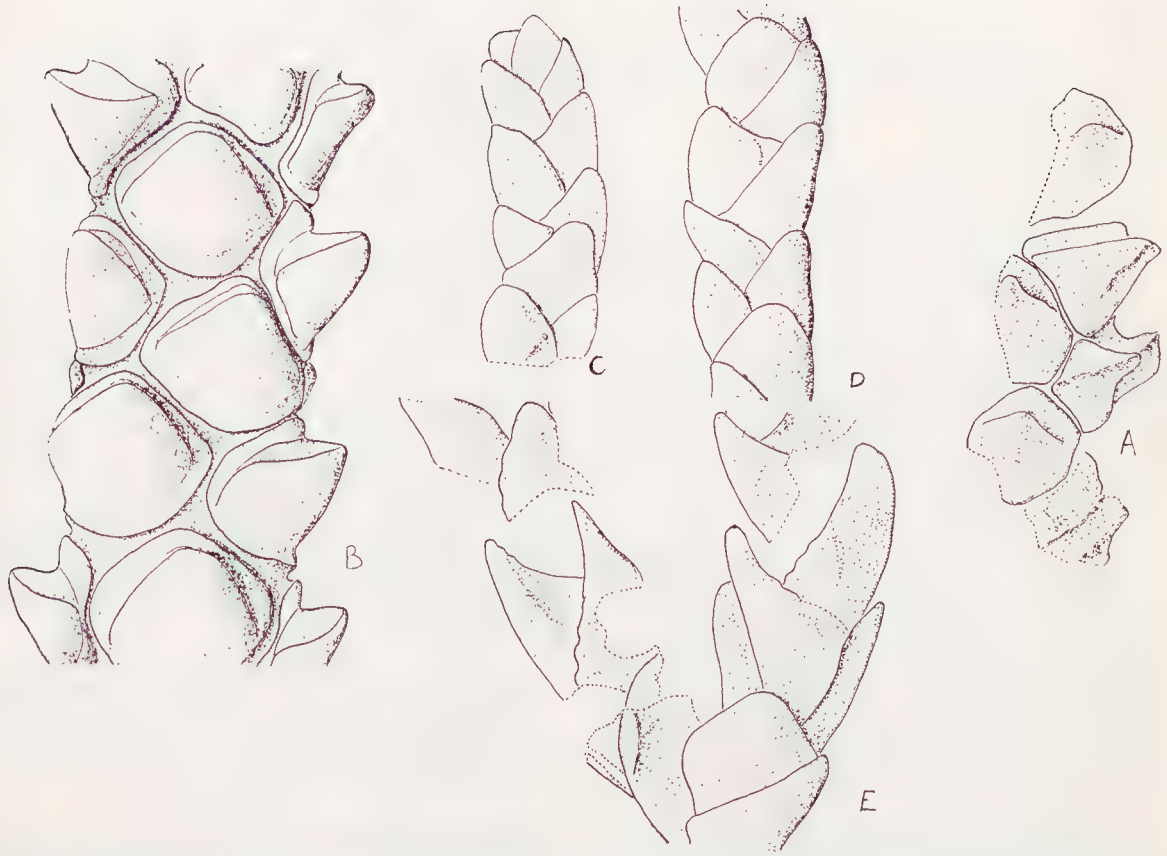


FIG. 8.—*Pagiophyllum feistmanteli*, A, B; *Alloccladus rajmahalensis*, C, D; E. A. Shoot with small leaves x 7. Univ. Queensland, F50769. B, Reconstruction of a shoot with small leaves x ca. 9. C-E. Parts of shoots showing variation in leaf form, and an apex (C), all x 7, Univ. Queensland, F50766-50768.

At the base on the lower surface the cuticle becomes thinner, and the cells become somewhat irregular. The same happens in the other species.

In this species there is some approach to rows of stomata; but it is not very clear. Rather, there are groups of stomata, two to five stomata in each, in which the stomata are very close set (Pl. 1G, Fig. 5F, B). These groups may be (but are not always) longitudinally orientated. Many stomata lie outside this arrangement. There are not rows such as are found, e.g. in *P. connivens* (of which I have examined Yorkshire material) or e.g. *Araucaria cunninghamii*.

At first sight the stomata look like those of *P. maculosum* Kendall (1948) but in detail their structure is believed to be different, and has been discussed above. The simplest interpretation is that expressed in the reconstruction in Figure 5E.

The hypodermal cells underlie the encircling cells, but so far as I could see, the inner wall of the subsidiary cells is not cutinised (Figs. 5C, G), unlike most species of *Brachyphyllum* and *Pagiophyllum*. The shovel like scalloping on the margins are shown in Figs. 5B. Cuticle preparations show whole files of epidermal cells turning out into them. They also contained hypodermis almost to their extreme edge.

Comparisons. Tenison Woods' description, considering its date (1883) is a good one, but *Al. milneanus* has since almost vanished from view. Walkoms' (1921) shoot is poorly preserved, but is identified as it shows the same leaf shape, is the right size, and comes from rocks of the right age. It is definitely distinct from *Pagiophyllum peregrinum* L. and H. (see Kendall 1948), and Walkom did not refer to Tenison Woods' work at all. My shoot is also probably distinct from *P. peregrinum* of Walkom (1919), from the Cretaceaous Burrum Series, but the conifer remains from the Burrum need further study before they can be discussed usefully.

Feruglios' (1934) material named *Elatocladus patagonicus* Fer. is stated to come from the Liassic of Patagonia, but Dr. S. Archangelsky tells me that it is really Permian. It agrees with *Al. milneana* in general form, no detail is known.

The age of *Al. milneana* is not satisfactorily settled. The New South Wales material and Sahni's

specimen (pl. 2, figs. 28, 29) from India are Lower Jurassic. However, the comparable material of Halle (see p. 161) is probably Middle Jurassic. I do not think any record comes from definitely Triassic rocks. Provisionally, the age could be given Lower to Middle Jurassic.

ALLOCLADUS CRIBBII sp. nov.

Pl. 1E, Figs. 1B-F, 4C, D, 5E, 7A, 11F, G.

? 1928 *Pagiophyllum peregrinum* Sahni, non Lindley and Hutton, p. 23-24, pl. 3, figs. 43-45, (shoots), 46, 47 (cuticle). Sher River, Satpura, Upper Jurassic.

Comparable specimens. Oldham and Morris, 1863, pl. 32, figs. 8,8a; Feistmantel 1877, pl. 42, fig. 2; McCoy in Stirling, 1900, pl. 2, figs. 1, 2, 5, pl. 3, figs. 10-16; Chapman, 1908, pl. 35, figs. 3 and ? 2; Halle 1913, pl. 8, figs. 42, 42a, pl. 9, figs. 3, 4; Arber, 1917, pl. 13, figs. 1, 8, 10; Walkom, 1921, pl. 3, figs. 4, 5; Sahni, 1928, pl. 2, fig. 20; Medwell, 1954, pl. 6, fig. 26.

Holotype. No. F5075. University of Queensland, Pl. 1H, Fig. 12M.

Locality. No. 5. Caledonia Colliery, Walloon Coal Measures, Lower Jurassic.

Diagnosis. Leaves closely appressed, whole shoot about 5 mm. in diameter, about 5 (2-6 mm.) long, (free part only) and 5 mms. (2-7 mm.) wide at widest, free part triangular. Leaves directed forwards, sometimes slightly falcate, making an angle of 20° or less with the shoot axis, 2.5-5 mm. thick (measured when compressed laterally). Leaf under surface convex, and keeled, lacking angles towards leaf margin; upper surface strongly concave. Leaf apex blunt. Branching feebly pinnate.

Cuticle of different thicknesses on two surfaces of the leaf, about 6μ below, about 3μ or less above. Stomata entirely scattered within their zones, showing no discernible arrangement into rows or groups except for two obscure zones at leaf base. Stomata dicyclic, but in about 30% of the stomata the encircling cells lying in contact, and in about 5% an encircling cell shared between two stomata. Ordinary epidermal cells square, often wider than long, 40μ x 50μ, often papillate, papillae mostly lying over the cell outlines, solid, about 10μ high, tending to point forward. Cell outlines distinct, thick, about 5μ, sometimes slightly bulging into the neighbouring cells. Stomata sunken in a rather open pit formed by 3-6 subsidiary cells, and encircling cells outside them; encircling cells not overhanging the pit.

Margin showing small scallopings, about 100μ high, and rather irregular, scallopings formed of 3-6 epidermal cells. Hypodermis not cutinised.

Description and Discussion. The material examined consists of a number of shoots collected by Mr. Harold Cribb (Geological Survey, Queensland) and myself at the No. 5 Caledonia Colliery, near Walloon, Queensland.

Only one branching specimen has been figured: if the specimen from Talbragar (Walkom 1921, pl. 3, fig. 4) is rightly identified, the branching is weakly pinnate to irregular. The angle the leaves made with the stem varies (Figs. 1B-F), but they are always close set, a fact which makes cuticle preparations somewhat difficult to obtain, for the cuticles tend to stick together. The leaf base is not clearly seen, but appears to be of the normal cushion-like sort (Fig. 7A). The leaf, like many living conifers, shows an obscure angle or keel down the lower (abaxial) leaf surface. This is present in those leaves compressed partly laterally, and so is original, not caused by collapse into a mould.

The cuticle though thick is somewhat brittle, especially the upper, making it difficult to see the whole surface, however, Pl. 1E, shows one of the more complete preparations, and Fig. 11F the stomatal arrangement in a less complete piece. The papillae usually are prominent, especially after staining, and are sometimes visible on the hand specimen, giving the leaf an attractive appearance rather like morocco leather. The stomata are less sunken than those of *Al. milneanus* (Figs. 4C, D), comparing with the stomata of e.g. *P. ordinatum* Kendall (1948). There is variation, however, and some stomata approach *Al milneanus* a great deal more closely than the usual sort reconstructed in Fig. 5E. The stoma is interpreted therefore, as being of the same essential sort as *Al. milneanus* and not like e.g. *P. insigne* Kendall (1948) in which the deep stomatal pit is formed by the subsidiary cells.

The scallopings on the margin are much smaller than in *Al. milneana,* resembling those seen e.g. in *Athrotaxis cupressoides* Hook f. or *Microstrobos niphophilus* Garden and Johnson; however, in some leaves at least groups of epidermal cells run into a scalloping, as in Fig. 5B.

Comparisons. Sahni's (1928) material had cuticle, on which the stomata were grouped only on one side, which so far as can be judged from the small figure, agree with those from my Queensland material. The leaves on Sahni's shoots are, however, longer than mine, but this is a variable character, and I set it on one side. Sahni's shoot is certainly not *Pagiophyllum peregrinum* which is amongst other things, amphistomatic.

The Victorian material of McCoy (1900) Chapman (1908) and Medwell (1954) known as *Brachyphyllum gippslandicum* McCoy resembles other material ascribed to *Al. cribbii* in its irregular branching (a point of difference between it and some *Brachyphyllum* species) and leaf outline. It is impossible to go further than this. The flora was originally thought to be Jurassic (e.g. Seward 1904, Medwell 1954) but it was discovered that at least some plant bearing beds are conformably overlain by marine strata with Middle Cretaceous fossils and it is now known that the Victorian "Jurassic" floras are in fact Lower Cretaceous (see Dettmann 1963 for full discussion).

Most of the records of *Al. cribbii* come from rocks of Middle Jurassic age, though some may be lower Jurassic. The Walloon Coal Measures were dated by de Jersey (1959) as Lower Jurassic, but later (de Jersey and Paten 1964) a Middle Jurassic age has been suggested.

TABLE I.

THE SPECIES OF *ALLOCLADUS* COMPARED

	Leaves.	*Margin*	*Upper Surface*	*Stomatal distribution and Cuticles*	*Stomatal details*	*Hypodermis*
Al. rajmahalense	Closely appressed, shoot like a cat's tail, diameter, ca. 2.5 mm. Leaves triangular, apex obtuse, about 2 mm. long and 2 mm. wide at widest.	Scalloped only at base, 100μ, otherwise scarious	Only slightly concave	In rows, running up to leaf apex, (probably) in separate zones towards leaf base. Orientation more or less longitudinal. Two cuticles of very different thickness: 7μ : 1μ.	Somewhat sunken in a pit whose top may (about one in 10) overhang	None seen
Al. cribbii	More or less closely appressed, shoot like a cat's tail, diameter 5 mm. or more, leaves triangular, apex obtuse, about 5 mm. long and 3 mm. wide at widest.	Scalloped, or not, along whole margin, 100μ, otherwise scarious	Strongly concave	In a mass, obscurely separating below in two zones. Stomata not in rows, orientation irregular. Two cuticles of different thicknesses: 5μ : 1-2μ.	Slightly sunken in a rather open pit	None seen
Al. milneanus	Standing out from shoot, shoot not like a cat's tail. Leaves triangular, apex acute, 8 mm. long 3 mm. wide at widest.	Strongly scalloped along whole margin, 1 mm. or more	Only slightly concave	In two indistinct zones along whole length of leaf. Stomata tending to be in rows, orientation irregular. Cuticles of about same thickness, (5-7μ).	Strongly sunken in a pit whose top may overhang	Cutinised

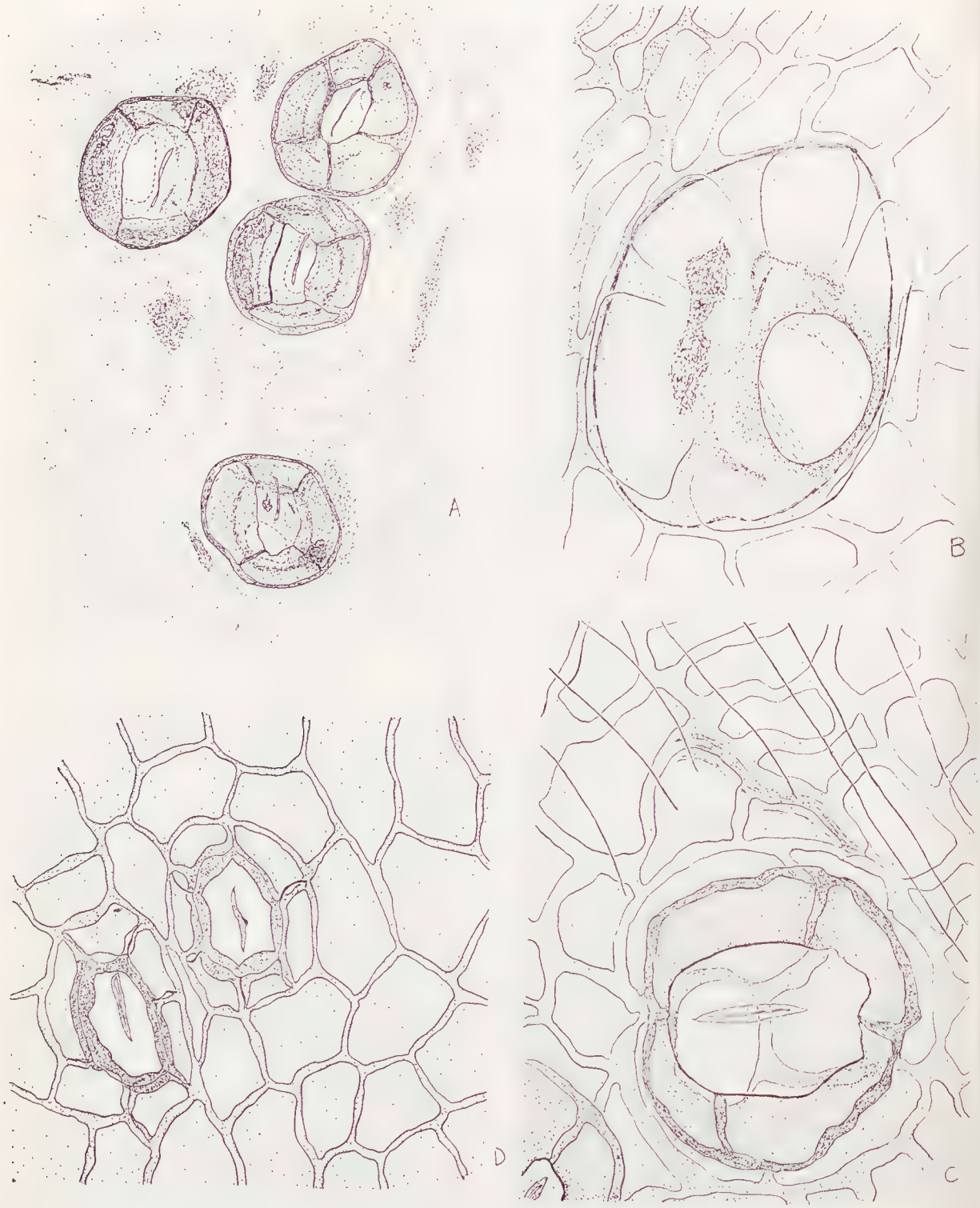


FIG. 9.—*Pagiophyllum feistmanteli* A. Part of the cuticle (rather oxidised) showing cells and stomata. x 400. B, C. Two stomata from outside (B), and inside (C), with hypodermal cells in C. x 600. A-C. Queensland Geol. Survey 705. D. Two stomata without overhanging cutin rim. x 600. University Queensland, F50769.

PAGIOPHYLLUM Heer

Pagiophyllum feistmanteli Halle

Pl. 1C, F, Figs. 1G, 2F, G, 7D, 7C, D, 8A, B9, 11E.

1879 *Pachyphyllum peregrinum* Feistmantel non Schimper, p. 28, pl. 12, figs. 3 and 9. Jurassic of Madras Coast, Vemavaram district. Pl. 11, fig. 5 distinct.

1892 *Brachyphyllum crassum* Jack and Etheridge non Tenison Woods, p. 385, pl. 18, Walloon, specimen here re-examined.

1913 *Pagiophyllum feistmanteli* Halle, pp. 76-78, pl. 9, figs. 17-17B, text figs. 17A-D. Large shoots, Jurassic of Antarctica.

1917 *Brachyphyllum crassum* Walkom non Tenison Woods, p. 92. Cited in a locality list.

1928 *Pagiophyllum feistmanteli* Halle: Sahni, p. 19-20, pl. 2, fig. 27. Feistmantel's holotype refigured.

1940 *Pagiophyllum feistmanteli* Halle: Florin, pp. 30, 63. Discussion.

1963 *Pagiophyllum feistmanteli* Halle: Bonetti, p. 39, pl. 7, fig. 3. Argentinian Middle Jurassic.

Comparable specimens. Feistmantel 1879, pl. 12, figs. 2, 2a; Halle, 1913, pl. 9, figs. 14, 14a.

Holotype. Feistmantel 1879, pl. 12, fig. 3.

Locality. Vemavaram, near Madras; Jurassic ? Middle Jurassic.

Diagnosis emended. Shoots more or less pinnately, but probably basically spirally branched. Ultimate shoots arising at nearly 90° from main shoot, from 6-12 mm. wide. Leaf bases rounded, sometimes slightly rhomboidal, about 3 mm. wide (2-5 mm.) and 4 mm. high (3-7 mm.). Free part of leaf forming chisel like or bluntly pointed projection, standing out at about 90° from the stem, or more when large, 1-4 mm. long. Junction of upper edge of free part of leaf and leaf base abrupt, at high angle and at about 0.5 mm. from upper margin of leaf base. Free part of leaf more or less rhomboidal in section, but lower surface more strongly keeled.

Cuticle thick, at least 3μ, or more or less same thickness all over the leaf. Stomata lying in two distinct zones, zones extending from basiscopic margin of leaf base towards acroscopic margin, but dying away towards acroscopic margin, and extending laterally from margin of leaf base onto flanks of free parts of the leaf. Upper surface of free part of leaf, and upper margin of leaf base free of stomata. Stomatal rows more or less regular, 8 (3-10) stomata high, two to five rows on leaf base with a few stomata not in the zones at the leaf base. Epidermal cells more or less square in irregular longitudinal rows of side 40μ, outlines 8-12μ thick, surface smooth.

Stomata dicyclic to irregularly tricyclic. Guard cells strongly cutinised round the stomatal pore, deeply sunken into the leaf, and themselves weakly concave. Stomatal pore of irregular orientation. Subsidiary cells four to six, often only four, two lateral and two polar members, forming a more or less rectangular pit over the guard cells. Cutinisation between subsidiary and encircling cells no stronger than between other cells of the leaf. Encircling cells of the first rank forming a chimney over guard and subsidiary cells, and walls of encircling cells often continued into a cutin collar, projecting up above general epidermal level. Encircling cells of second rank (when present) lying on general epidermal level, and unspecialised. Whole stomatal apparatus about 80μ in diameter, opening of chimney over stoma about 20μ, depth of pit about 50μ (?). Hypodermis sometimes cutinised, showing elongated cells. Venation unknown.

Description. The material available is specimen F711 Queensland Geological Survey, and I thank Mr. A. K. Denmead, Chief Government Geologist, most warmly for lending me the specimen, and a second larger specimen (Pl. 1C), from Tannymorel Colliery, near Warwick. No. 711 is the same one as that mentioned by Jack and Etheridge (1892) and Walkom (1917) and comes from the Clifton Colliery in the Walloon Coal Measures. The specimen is shown in Fig. 1G. The diagnosis is drawn also on Halle's (1913) account, for he had larger (though uncutinised) shoots.

As shown in Halle's figures and Pl. 1C, the branching is more or less pinnate and in Pl. 1C the four branchings visible all seemed to be lateral, rather than spiral twisted into one plane. However, from the way the material permeates the rock it is clear that branching is not rigorously in one plane. A useful model might be *Araucaria cunninghamii* Ait. in which the ultimate branching is also mostly but not all pinnate (the penultimate is definitely spiral).

Over most of F711 the plant material has vanished, but the second specimen is well preserved. On that part of 711 where the plant material has gone the leaf bases show a rounded depression, and the free parts a still deeper, somewhat angular depression not touching the margin of the leaf base impression (see Feistmantel 1879, Sahni, 1928, pl. 2, fig. 27 and Fig. 19). A somewhat similar appearance is shown by Yorkshire specimens of *Brachyphyllum mammillare,* but *Pagiophyllum feistmanteli,* and similar shoots, differs in that the junction of the upper surface of the free part of the leaf, and of the leaf base, lies somewhat below the upper margin of the leaf base, and is angular (see Figs. 2F, G, 7C, D, reconstruction in Fig. 8B, and cf. Kendall 1949 fig. 2C, and above). Moreover, the free parts of the leaf of my material occupied only part of the leaf base regardless of whether they were large or small, and Halle's and Bonetti's figures show the same. In *B. mammillare,* on the other hand, the larger leaves occupy the whole leaf base. The angle at which the free parts of the leaf projects varies, the angle being greater (up to or over 90°) in the larger leaves, and on these larger leaves with a strongly projecting free part, the rhomboidal section of the leaf is more marked (cf. Figs. 7C and see Halle 1913, fig. 17), whereas in the small leaves the upper surface of the free part is merely slightly convex. The cuticle at the edge of the leaf bases (marked by elongated cells) is folded, and the edge is marked by a trench in one or two places on the specimen (Fig. 8A): the whole leaf base was therefore swollen. An extremely similar apearance is seen in juvenile foliage of *A. cunninghamii* and *A. araucana* where the awl-like (or flat, *A. araucana*) leaf springs from near

the centre of a rhomboidal swollen leaf base. As the branch increases in size the leaf base expands, the free part coming to occupy less and less of the leaf base, exactly as in my shoots. Furthermore, the older leaves, like the larger leaves of *P. feistmanteli* tend to project backwards. However, the leaf in *A. cunninghamii* is always longer than in *P. feistmanteli*, and (perhaps connected with this), stomata are present on the upper leaf surface, and along the acroscopic leaf base margin. *A. excelsa* (juvenile) is also similar (see Florin 1931).

The cuticle is brittle, despite its thickness, and it was not possible to obtain a complete leaf, and the stomatal distribution is deduced from pieces, of known origin (Pl. 1F and Fig. 6D). The cuticle from the upper surface of the free part of the leaf adjacent parts of the leaf base is sometimes thinner than the rest. In 711 the cuticle is not well preserved, (Fig. 9A), but in as much as can be seen, particularly in the stomata, it agrees with F50769. The hypodermis is, however, never clearly seen, appearing as a layer of cells under the cuticle (Fig. 9C), or as masses of delicate but distorted cuticle.

The stomata are often the most distinct feature of the cuticle, appearing like miniature cartwheels with four to seven spokes. Their structure is difficult to make out. The following is the easiest interpretation. Focussing showed the stomatal pore, and (viewed from inside) the subsidiary cells at a slightly different focus. Their radial walls continued up as the walls of the encircling cells (Figs. 9B, C, D, 11E). The wall between subsidiary cells is not especially cutinised, and the possibility was considered that the stomata were in fact monocyclic (cf. *Pinus thunbergii* Parl. Florin 1931, and *Pagiophyllum maculosum* Kendall (1949). However, stomata compressed a little on one side show a cell wall which is not present in the monocyclic conifers with a deep stomatal pit. Also, comparison is closer, in respect of cells though not of the pit, between *A. feistmanteli* and the dicyclic *Abies*, in which both subsidiary and encircling cells contribute to form the pit, than between *A. feistmanteli* and the *Pinus* species with a deep pit. I have examined *Abies pinsapo* Boiss, *A. nordmanniana* (Steven) Link., *P. contorta* Dougl. and *P. densiflora* Sieb et Zucc. The most similar stoma I have seen is that of *Cycas revoluta* (cf. Figs. 14, L. M), and the *Cycas* stomata in 14M, would probably do as a reconstruction of the *P. feistmanteli* stoma. To refer again to *Araucaria cunninghamii*, here the stomatal pit in the juvenile leaf is formed from both subsidiary and encircling cells, and occasionally stomata looking like *P. feistmanteli* can be found. Generally, however, the encirling cells do not overhang the pit. *Pagiophyllum maculosum* Kendall looks rather similar, but the chimney over the stomata is formed by the subsidiary cells. A further possibility was that the stomatal chimney was formed of three tiers of cells. However, observed from above (Fig. 9B) the encircling cells join onto the other epidermal cells, while the line that might have been the cell outline, corresponds to the line between the subsidiary cells and the collar of cutin over the stomatal pit of *Athrotaxis* Don (Florin 1931, Townrow 1965). Presumably, as in *Athrotaxis*, the cutin collar is in origin fused papillae, borne in *P. feistmanteli* on the encircling cells. The collar is not always present, however.

As noted, the cuticle at the junction between leaf bases shows elongated cells, some of which are shown in Fig. 9B top right. Some hypodermal cells are shown in Fig. 9C.

Discussion. There are probably no fully described fossil species with which *P. feistmanteli* can be confused. The form of the leaves has already been compared with *B. mammillare*, which may look similar, while in *B. desnoyersii* Saporta (see Kendall 1947) the leaves stand out from the shoot, but form a small pyramid, the whole leaf vase being involved.

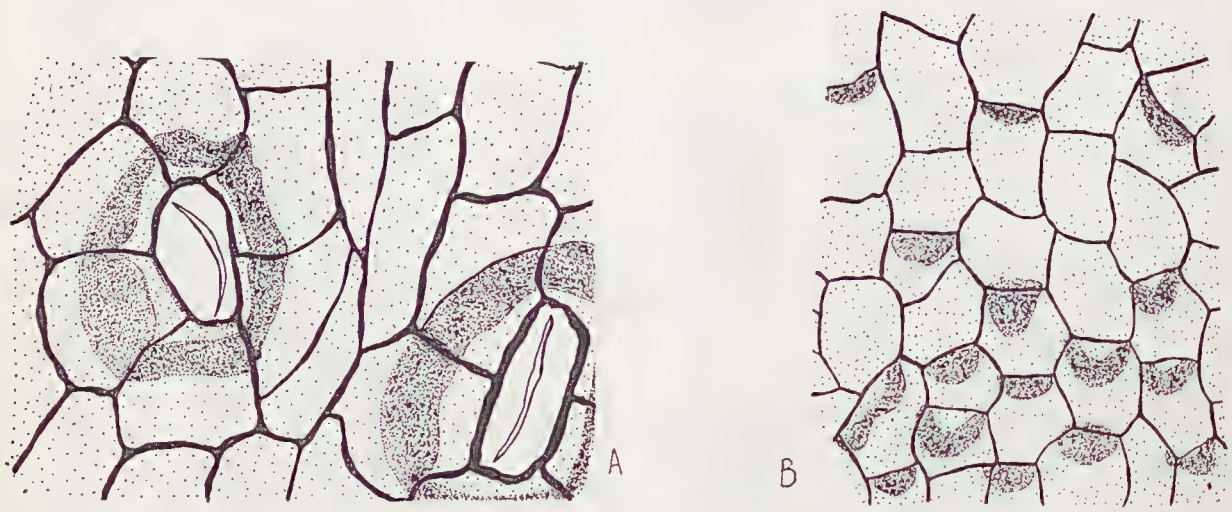


FIG. 10.—*Allocladus rajmahalense*. A. Two stomata, from lower surface of leaf. x 600. B. Cuticle of lower surface of leaf, near leaf base, showing papillae. x 400. Univ. Queensland, 50767.

In cuticle also *P. feistmanteli* differs from other described *Brachyphyllum* and *Pagiophyllum* species (Kendall 1947-1952, Wesley 1956, Archangelsky 1963), which mostly have dicyclic but rather open stomata, or else papillae on the subsidiary cells. *P. maculosum*, which could be confused has been dealt with above.

In the Indian Mesozoic there are several shoots, all incompletely known, looking rather like *P. feistmanteli.*

(*a*) *Echinostrobus expansus* of Holden (1915, see also *Feistmanteli* 1876 pl. 9, figs. 6-9, pl. 10, figs. 3, 4; 1879b, pl. 11, figs. 5, 5a; Sahni 1928, pl. 3, fig. 38), consists of a small shoot system showing pinnate branching, apparently opposite (but probably spiral) leaves which agree with my material in showing a tiny chisel like point arising some way below the upper margin of the rounded swollen leaf base. Further, the cuticle shows more or less the same disposition of stomata as *P. feistmanteli*, including a non stomatiferous "midrib" but differs in showing less regular stomatal rows. The stomata, judging from the figures and descriptions (especially Holden pl. 11, fig. 6) are like those of *P. feistmanteli.* The epidermal cells, however, are shown as differently shaped. The description would doubtless be reworded to-day, and the figures drawn larger, but it seems to me that Holden's material differs from *P. feistmanteli* only in details and proportions and stands with it, when being compared with other *Brachyphyllum* and *Pagiophyllum* species.

Sahni (1928 p. 33, pl. 39, figs. 41 and 42) placed Holden's material with another cutinised shoot in his *Brachyphyllum expansum* var. *indicum*, but judging from the small figures, this material differs from Holden's in leaf shape, stomatal distribution (noted by Sahni) and stomatal details. I here identify Sahni's shoot with quite a different plant (see above). Still another shoot named *B. expansum* is shown by Feistmantel (1887b, pl. 11, figs. 4, 4a, and Sahni, 1928, pl. 3, fig. 39 (Feistmantel's pl. 11, fig. 4, refigured) and 40). Feistmantel shows this shoot having small points to leaf bases, much like Holden's *B. expansum*, and Sahni's cuticle preparation (fig. 40) though far too small to show detail is comparable with Holden's. The shoots differ, though not widely in the shape of their leaves, Holden's being rounded in outline, and in branching, which is regularly pinnate in Feistmantel's shoot. The shoot may be identical with either Holden's shoot or *P. feistmanteli*, or might be specifically different, I cannot decide on the information available. It would seem clearly to belong to the same group.

(*b*) *Echinostrobus rhombicus.* Feistmantel (1887a, pl. 11, figs. 6-11; 1879, p. 30, pl. 12, figs. 2, 2a, 10, 10a; Halle 1913, pl. 9, figs. 15-16a; Sahni 1928, pl. 1, figs. 23-25, to which some of the specimens cited on p. 167 as comparable with *P. feistmanteli* may belong), consists of long sparingly branched shoots with very regular rhomboidal leaf bases. In some figures (see especially Sahni 1928, pl. 2, fig. 25) there appears to be free part to the leaf looking like the free part of *P. feistmanteli*, though smaller. No cuticle is known.

The shoot called *Brachyphyllum divaricatum* by Feistmantel (1877a, p. 59, pl. 10, figs. 1, 1a; Sahni, 1928, p. 23, pl. 2, figs. 30, 31) differs from any of the above species, in that its thorn like leaves occupy the whole of the leaf base, and are longer and more acute than is, at least normal in the material otherwise compared with *P. feistmanteli.*

I suggest that possibly the three species *P. feistmanteli*, "*E. expansus*" of Holden and *B. rhombicum* form a group of *Brachyphyllum*-like conifers that could form one genus. However, not having seen material of the Indian shoots, I refrain from moving the Indian specimens at present. It would seem that this little group (if real) is Gondwanan, and not Northern. *P. feistmanteli* comes from floras usually given as Middle Jurassic (Halle 1913), (Sahni 1928, de Jersey 1963). *E. rhombicus* and "*B. expansum*" of Holden come from the Jabalpur Series, Upper Jurassic or Lower Cretaceous, and from other localities, probably Jurassic.

P. feistmanteli cannot be classified on its shoot alone, but, as with several other *Brachyphyllum* and *Pagiophyllum* species, there is a strong suspicion that it stands near *Araucaria* especially Sect. Eutacta. As noted, the rather unusual leaf shape is matched in *A. cunninghamii* juvenile foliage, while the stomata are similar, rarely very similar. The branching pattern of the ultimate shoots is also, in all probability, the same. The differences lie in stomatal distribution and leaf length.

Brachyphyllum differs from *Pagiophyllum* only in that the free part of its leaf is shorter than the leaf base cushion, not projecting beyond it (e.g. Wesley 1956). *P. feistmanteli* crosses this admittedly artificial boundary, but having been once put in *Pagiophyllum* I see no gain in moving it now. Its position in *Pagiophyllum* can in any case be merely provisional.

CONITES TENISON WOODSI nom. nov.

Pl. 1B, Fig. 2B.

1883 "Cone of *Walchia milneana*" Tenison Woods, pp. 164-165.

With the foliage called originally *Walchia milneana* (now *Allocladus milneanus*) Tenison Woods (1883, p. 164), described a structure he regarded as the male cone. The original is in the McLeay Museum, No. 36. It is neither of the specimens figures in Tenison Woods pl. 6, figs. 7 and 8, but the description refers to it.

The single specimen represents a more or less median longitudinal section, and except for minute cubes of carbon, no plant material is left. The specimen is a rather spike like infloresence (cone) containing at least 30 units, (Pl. 1B), each unit consisting of a bract and an axilliary structure, which, for simplicity, is termed the seed scale complex. The units are almost certainly spirally inserted, not in pairs, for passing up the cone, successive units appear in (approximate) saggital section, to a view which is almost certainly abaxial surface exposed. The appearance of paired units arises from the circumstances that the fossil is a longitudinal section. It is not clear whether the bract is separate from the seed scale complex, but from the difference in level between the two (Fig. 2B), I think it is. The complex consists of a supporting portion, curved in distally, on the

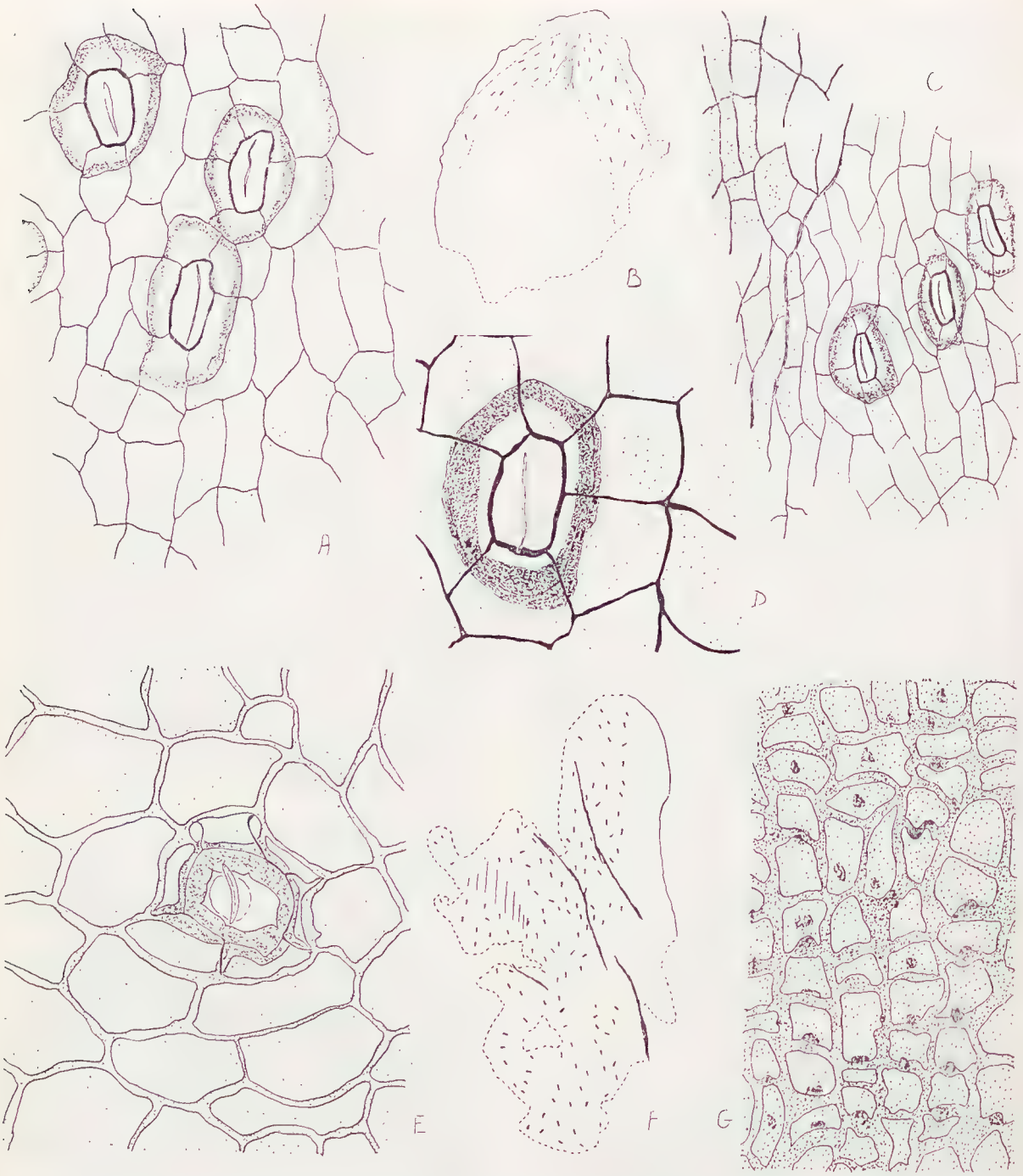


FIG. 11.—*Allocladus rajmahalense*, A-D; *Al. cribbii*, F, G; *Pagiophyllum feistmanteli* E. A. Cuticle from upper leaf surface x 400. B. A leaf, showing number and arrangement of stomata on upper leaf surface; close lines represent "midrib". Possibly not all stomata shown. x 10. C. Cuticle from lower leaf surface, with stomata, and thick cuticle (top left) x 300. D. A stoma from the upper leaf surface x 600. Univ. Queensland, F50766, F50767. E. Stoma with cutin rim forming chimney over stomatal pit, Univ. Queensland, F50769. F. Cuticle from upper surface of leaf with stomata, margin to right, vertical lines, folded area where stomata not visible. x 20. G. Cuticle from lower surface of leaf, showing papillae. x 400. Univ. Queensland, F50760.

adaxial surface of which there are three to five scale-like structures (as noticed by Tenison Woods). Without plant material it is impossible to say what these structures are. In places (Fig. 2B), there may be a micropyle seen, and my guess is that they are seeds. They could equally well, however, be a cupular investment of the seed, or projection of the main part of the complex, unconnected with the seed.

The only evidence that the shoot and this cone belong to the same plant is Tenison Wood's statement that they are associated in Ballimore district. The lithology of the matrix is, however, not identical for the cone and supposed shoot, and I doubt whether they come from the same locality.

There is far too little information to attempt an adequate comparison, however, the probability is that the cone belongs to the Coniferales. Within the conifers comparison seems possible with *Palissya* Bronn (see Florin 1944), but if the bract is indeed separate from the seed scale complex, it differs sharply from *Palissya*, and the resemblance may well be only superficial. A rather similar looking fossil is figured by Edwards (1934, pp. 100-102, pl. 3, figs. 5, 6) as *Palissya bartrumi*, from the Jurassic of New Zealand. I consider Tenison Woods' cone no further, except that if it does belong with the foliage called *Allocladus milneana*, it, even on present information, removes that plant from close comparison with any living conifer; also from *Lebachia* Florin (*Walchia* pars.). I doubt if the resemblance to *Ernestiodendrom* (*Walchia*) *filiciforme* (Sternberg) Florin is more than superficial.

The best way of dealing with this specimen would seem to be to transfer it to the non commital genus *Conites* till more can be found out about it.

Diagnosis. Spike-like fertile structure at least 7 cms. long and 1 cm. wide, consisting of about 30 units spirally arranged up the cone axis. Each unit double, with basiscopic (subtending) portion, and an acroscopic (axilliary) portion. These two probably separate. Acroscopic portion curved inwards distally, and having on its upper surface three to five more or less oval bodies, about 1.5 mm. high and 1 mm. wide, possibly seeds.

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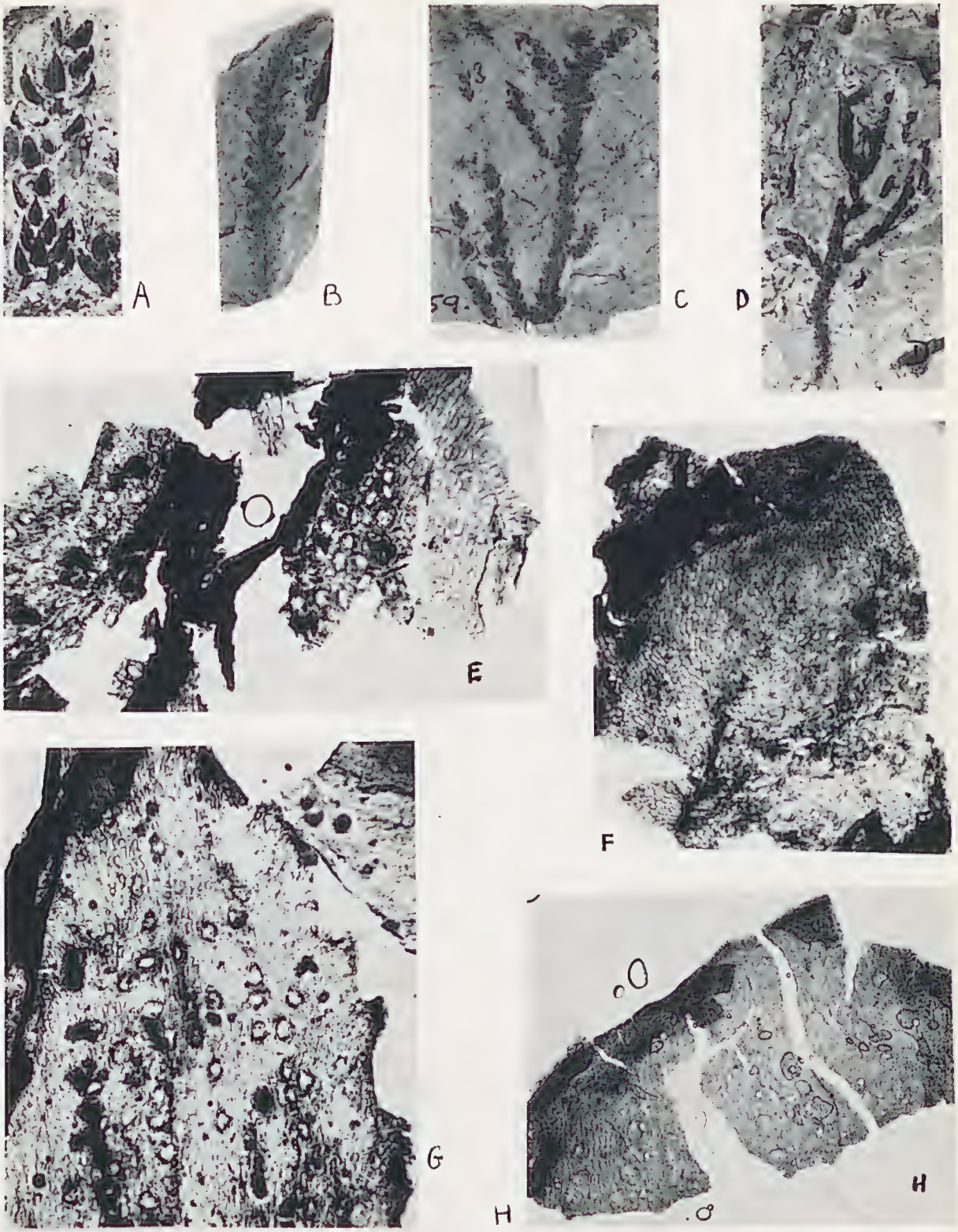

Plate I.—A. *Allocladus milneanus*, holotype, x 1. MacLeay Museum 136. B. *Conites tenison woodsii;* the specimen x 1. MacLeay Museum 36. C. *Pagiophyllum feistmanteli*, branching specimens, x 1. F50769. E. *Al. cribbii*, upper cuticle, stomata and margin. x 25. F50761. F. *P. feistmanteli*, cuticle, a stomatal zone lower left (arrow) x 25. F. G. *Al. milneanus*, upper cuticle, stomata and margin. Macleay Museum 136. H. *Araucaria crassa*, lower cuticle, cells, stomata and margin x 25. MacLeay Mus. 137.

ON VOLTZIOPSIS, A SOUTHERN CONIFER OF LOWER TRIASSIC AGE

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(With seven text figures and one plate.)

ABSTRACT

Shoots ascribed to *Voltziopsis africana* Seward are described, with cuticular detail. These compare very closely with the shoot system, with an attached seed cone, called *V. wolganensis* sp. nov., which is associated with pollen of the *Strotersporites* Wilson sort. The shoot called *Brachyphyllum angustum* Walkom is redescribed though Walkom's specimens cannot be found, and proves to be so close to the species referred to *Voltziopsis* that it is reclassified *V. angusta* (Walkom) comb. nov. The material considered comes from the Lower Triassic of New South Wales, and reasons are given for considering all *Voltziopsis* specimens Lower Triassic also. The classification of *Voltziopsis* in the Coniferales is discussed.

INTRODUCTION

The genus *Voltziopsis* Potonié has been known for a long time, but only from poor material, and has remained, despite Florin's (1944) description, a rather vague entity. In the Geological and Mining Museum, Sydney, there is a remarkable specimen showing a seed cone attached to a large spray of foliage. The cone agrees with *Voltziopsis*, so the foliage is referred to *Voltziopsis* also. With this information, the shoots of the type species, *V. africana* Seward can be re-described with cuticular detail, and another shoot placed in the genus. So redefined *Voltziopsis* proves to be a small genus, probably only Lower Triassic, comparing in a very interesting way with the taxodiaceous genera, *Cryptomeria* Don and *Athrotaxis* Don, and with the isolated cone unit *Swedenborgia* Nathorst. It seems unlikely that *Voltziopsis* is derived from the southern Permian conifers.

DESCRIPTIONS

Family Voltziaceae

Genus **VOLTZIOPSIS** Potonié

Type species: *Voltziopsis africana* Seward

1899 *Voltziopsis* Potonié, pp. 303-304, fig. 304.

1900 *Voltziopsis* Potonié, pp. 503-504, fig. 29, a-g.

1934 *Voltziopsis* Potonié (*V. africana* Seward), Seward, pp. 387-388, pl. 19, figs. 4, 5; pl. 20, figs. 9, 10.

1944 *Voltziopsis* Potonié: Florin, pp. 486-488, pl. 181-182, figs. 3-5, text fig. 53.

(Further references are given under the species.)

Diagnosis (emended). Conifers showing irregularly and sparingly branched shoots. Leaves dimorphic even on same shoot; smallest scale-like, about 3 mm. long and 2 mm. wide, more or less triangular, apex rounded or acute, about half as thick as broad. Largest leaves 2 or 3 cms. long and 3 to 5 mms. wide, directed forward, or forwards and outwards, and if the latter, showing tendency to be twisted into two rows up the shoot. Long leaves 2 or 3 mms. thick at base. All leaves having a thin but not scarious margin, lower (abaxial) surface rounded or angled, but lacking a distinct keel, upper surface usually concave, or flat, rarely slightly raised over the midrib. All variants between extremes of leaf form found.

Cuticle thin, 0.5-1.5μ (all measurements from folds) of different thickness on two leaf surfaces. Leaf unequally amphistomatic, with most stomata on the upper surface: all epidermal cells set more or less in rows and stomata also usually in obscure rows, orientation longitudinal or various. Lower leaf surface showing equidimensional or elongated epidermal cells, and a few stomata mainly towards leaf base. On upper leaf surface cells at margin as those on leaf under surface, towards "midrib" cells set less regularly, and cuticle thinner. Most stomata borne towards the midline of the leaf, but (probably) a non-stomatiferous "midrib" present. Cuticle surface smooth, cell outlines not thick (about 4μ or less), straight and unpierced by holes. Stomata chiefly mono-cyclic, rarely dicyclic with one to six encirling cells. Stomata showing four to about eight subsidiary cells, having a smooth dorsal surface and not produced over the stomatal pit. Subsidiary cells disposed with two lateral and two terminal members or in a ring of four to six equal cells. Encircling cells, where present, unspecialised except by position. Guard cells only slightly sunken in a more or less rectangular pit, feebly cutinised. No cutinised hypodermis present. Venation unknown.

Pollen cone unknown.

Seed cone terminal on a short branch just like a normal vegetative branch, cone cylindrical about 2.5 cms. long and 1.5 cms. wide, consisting of (estimated) 25 units closely packed together. Unit consisting of bract and cone scale (= seed scale complex or flower of Florin). Bracts forked, narrow, as long as or longer than the cone scale. Cone scale consisting of a thick but flattened stalk expanding apically into five (rarely six) lobes, not inserted quite at the same level. Each lobe bearing a single inverted seed, free from the lobe, but

FIG. 1.—*Voltziopsis africana, A; V. angusta,* B-D. A: A long shoot, lower right. To top left, the other common conifer from the Bulli roof shales. x 1. F 22426. B: Specimen showing a long leaved and a short leaved shoot, arrow marks branching (Fig. 2F). x 1.5. F 13022. C: A rather narrow shoot, with long narrow leaves. F 13021. D: Impression of a shoot with leaves of medium length. F 13022. Both x 7.

lobe showing seed stalk adnate to it. Lobes obtuse or pointed. Total length of cone scale about 8 mms. Seed (or ovule) egg shaped, with micropyle at narrower end, about 1.5 mm. long and 1.0 mm. wide. Cone probably disarticulating when ripe (or when with unfertilised seeds).

Stalk of cone scale cutinised, showing thick (3μ) cuticle over its abaxial surface, thinner cuticle over (supposed) adnate seed stalk, this surface without stomata. Lobes of cone scale showing cuticle of different thickness on two sides, showing cells more or less rectangular or trapezoid, set in somewhat irregular rows, especially irregular on thinner (presumably upper, or adaxial) surface. Stomata as on leaf; present (?) only on upper lobe surface. Bract with similar cuticles to lobe of cone scale, but unequally amphistomatic. Details of seed unknown.

Discussion. (1) *Description. Voltziopsis* was first suggested by Potonié (1899, pp. 303-304, fig. 304) to include isolated cone units and shoots from East Africa, and also a variety of other fossils, such as *Leptostrobus* Heer, now known to be different. He did not formally diagnose his genus, nor declare a type species. This latter was done by Seward (1934), as *V. africana* Seward. Florin (1944, pp. 486-488) re-described Potonié's material (including some of a later collection), and definitely excluded from the genus all but the five or six lobed seed scale complexes subtended by a forking bract. Since a cone is now found in connection with foliage, *Voltziopsis* returns to Potoniés original concept of it, only without *Leptostrobus* &c.

The genus now comprises (1) *V. africana;* the type species consisting of shoots with cuticle, and isolated non cutinised cone units (not seen by me): (2) *V. wolganensis;* consisting of a single specimen, cutinised, showing attached shoot and seed cone and associated pollen: *V. angusta,* cutinised shoots. As will be seen, the evidence for ascribing shoots to cones is circumstantial, in the case of *V. africana,* and the evidence is discussed under the species.

The branching pattern is best seen in F6620 (Pl. 1E), but other figures (Walkom 1925, pl. 30, fig. 5; Seward 1934, pl. 19, fig. 5) provide further evidence. Plainly there is no trace of a long shoot/short shoot system seen in certain species of *Voltzia* Brongniart (e.g. Schimper and Mougeot 1844 pls. 6 and 7), or in *Metasequoia* Miki among living conifers.

The dimorphism of the leaves has been noted by all authors though it is most extreme in *V. wolganensis* (Pl. 1B). However, this leaf dimorphism is somewhat different from what is seen in, e.g. *Dacrydium bidwillii* Hook f., for in both long and short leaves the leaf shape is the same (or closely similar); the variation is in size rather than form. the gross form of the leaf is the same in all three species treated here; the lower surface is seen to be somewhat raised, and where a leaf lies apart from the rest (Figs. 1C; 2B, D) this appearance, on Walton's compression theory, arises because the upper surface was concave, and the matrix has formed a mould upon which the leaf has collapsed. Seen compressed laterally, the leaf is thick, but there is no sign of a keel (Figs. 2B, C, F), presumably therefore, the leaf lower surface was rounded-convex. In some specimens (Fig. 2D) the leaf margin is seen to be thin, and this is confirmed from cuticle preparations which sometimes show (Fig. 4D) compression folds a little way in from the margin, though in *V. africana* the leaf may be nearly flat (Fig. 5A). However, the cells at the margin are not identical on both cuticle surfaces, so the margin was not scarious. A similar appearance can be seen in the living *Araucaria excelsa* Lamb, in which the thick leaf thins abruptly to a thin but not scarious margin. The leaves may therefore be visualised as being rather like the leaves of *Athrotaxis selaginoides* Hook, in which, in fresh material, the under surface is not keeled, though the leaf is thick and the upper is flat or slightly concave or rarely ridged. In this conifer, the leaf is also unequally amphistomatic to epistomatic, but all the stomata on the upper leaf surface form a dense mass, and no "midrib" is present (Florin 1931).

The cuticle proved troublesome to prepare. The cuticle is thin, and the material apt to break up into cubes about 2 x 2 mm. or less. This means that stomatal distribution has to be deduced rather than observed. A difference in cutin thickness can be made out. By analogy with very many living conifers with more or less appressed small leaves, the thinner cuticle is supposed to be from the upper (adaxial) leaf surface, and the thicker one from the lower (abaxial) surface. The thicker cuticle (lower), shows rectangular or irregularly elongated or equidimensional cells (Figs. 4D, E) and few or no stomata. In *V. africana,* which has a cuticle easier to prepare than the others, most stomata on the lower leaf surface are found near the base of the leaf. The thinner (upper) cuticle is similar at the leaf margin (Figs. 5A; 6A) but shows stomata towards the middle of the leaf. Granted that the cuticles are correctly ascribed to their leaf surface, it is clear that most of the stomata are on the upper leaf surface. In *V. africana* and *V. wolganensis* there are some stomata on the lower leaf surface, though they are few (Fig. 4E; Pl. 1D). For *V. angusta* I was unable to find any stomata on the thicker cuticle, and here the leaf may be completely epistomatic. The cuticles are remarkably unadorned, in all species papillae (over stomata or not), simuosities in the cell outline or holes being quite absent.

The cone details are based mainly upon the single specimen F6620, shown in Pl. 1C which being much better preserved sheds light on the cone units of *V. africana.* No difference can be detected between the branch bearing the cone and any others, both bearing leaves of the same sort. The number of cone units seen on two sides is 12 or 13, and I suppose an equal number lay on the other surface. The whole forms a dense cone-like structure, each unit overlapping half to three quarters of the one above. The arrangement of units is spiral. The form of each unit is uniform, but the sizes of the parts varies considerably (a matter discussed below). The bract is forked about two thirds the way along its length (Florin 1944, pl. 181, fig. 3, text-fig. 53 and Figs. 3A, C) and cuticle preparations from it show that it is amphistomatic. The stalk to the cone scale (= seed scale complex of Florin) is thick but still wider (Fig. 3F), so that it was flattened. The cuticle of a

FIG. 2.—*Voltziopsis africana* A, B, D, E; *V. wolganensis*, C; *V. angusta* F. A, B, Apices of two shoots, with rather long narrow leaves. F 22426 and 534. C, D, F: Parts of shoots with leaves, upper surface slightly raised (C), concave, and leaves twisted into two rows (D) F 2260, F 22426, F 13022. All x 7. E: A length of shoot with untwisted leaves x 1.5. 2938.

lobe is shown in Fig. 5D. The cuticle of the lobe shows a strip of thinner cuticle with narrower cells at one edge. The strip coresponds in position to a low ridge running from the seed to the cone scale stalk, interpreted by Florin (*loc. cit.*) and I as a seed stalk, which, since its cuticle is continuous with that of the rest of the lobe, was adnate to the lobe (cf. Tison 1909 on *Saxegotha conspicua* (Lindl.)). The five lobes do not all fit onto the stalk at quite the same level (Fig. 3F), a situation slightly recalling *Pseudovoltzia* Florin. Compressed laterally the lobes were thick (Fig. 3F) possibly triangular in section, and probably the whole unit lapped round the cone axis, for parts of some lobes are folded (Fig. 3A). The cuticle of the lobes is shown in Figs. 4B, D), and like the leaves shows cuticles of different thicknesses with a few stomata seen only on the thinner. As for the leaves it is supposed that the stomata were borne (or chiefly borne) on the upper surface of the lobe, though the preparations are so small that there could very well be a few stomata, as on the lower surface of the leaf, that have been missed.

A point of considerable interest is that the cuticle, including stomata, of both leaf and cone scale, is identical, though the stomata on the cone scale are of the simpler sort seen on the leaf. This provides another fragment of evidence that one may properly associate organs on the strength of their similar cuticle.

The material described by Florin (1944) was not well preserved, and with some doubt, the seeds were reconstructed as upright, (text-fig. 53). However, in *V. wolganensis* it is now almost certain that they are inverted, though without cuticle preparation to demonstrate the micropyle, the matter is not quite settled. At the distal (chalazal) end the seed passes smoothly into the fused seed stalk, but at the other end, the seed is separate from the lobe, and of extremely thin material, like the micropyle of e.g. *Umkomasia* Thomas where one can demonstrate the various layers expected at the micropyle (see Harris 1964, pl. 2 for example). Despite several efforts, I was not able to get a cuticle preparation from a seed that could be interpreted. Only wisps of excruciatingly thin cuticle remained.

From the comparative abundance of isolated cone units, it may be that the *Voltziopsis* cone disarticulated when ripe, or perhaps if the ovules were not pollinated, as happens in some species of *Araucaria*.

(2) *The age of Voltziopsis. Voltziopsis* has always been supposed to be Triassic. Seward (1934) with hesitation dated his material of *V. africana* from East Africa as Upper Triassic, and this is accepted by Florin (*loc. cit.*), Carpentier (1935) placed his material, also hesitatingly, in the Lower Triassic. I suggest that *Voltziopsis* is only Lower Triassic. There are several points. (*a*) *Voltzia* cf. *liebeana* of duToit (1927) from the Molteno, once thought to be *Voltziopsis* (Florin 1940) is now placed with *Rissikia*, a very different conifer. (*b*) The grounds on which Seward (1934) was inclined to place his flora in the Upper Triassic were essentially the presence of *Baiera*-like and *Desmiophyllum*-like leaves. In the Gondwana Triassic these are two very poorly known complexes that probably range the Triassic, and Jurassic too. The evidence they provide is unconvincing. On the other hand the Tanga flora contains no undoubted corystosperms, in particular none of the exceedingly common (indeed dominant) species such as *Dicroidium odontopteroides* (Morris) Gothan) mainly an Upper Triassic species. This negative evidence does not of itself invalidate Seward's conclusions, but it does make his flora a rather remarkable one, if Upper Triassic. (*c*) Carpentier's flora containing *Voltziopsis* contains various other conifers, the leaf *Thinnfeldia callipteroides, Lepidopteris madagascarienses,* but again, no definite corystosperms, unless the single pinna tentatively ascribed to *Supaia* White (pl. 2, fig. 5) is a *Dicroidium* pinna. This flora comes from the same series of rocks that have since been dated on their vertebrates as Lower Triassic (Lehman 1952, pp. 190-196; 1961, pp. 151-152). (*d*) In New South Wales the foliage ascribed to *V. africana* comes only, as far as I can discover, from the roof shales of the Bulli Seam in Hennelly's (1958) Transition Zone; a horizon no younger than Lower Triassic age, and also incidentally with *Ginkgo*- and *Baiera*-like leaves,and possibly basal Triassic (see Balme 1963). It is not known for certain where the specimen of *V. wolganensis* comes from, but the best guess (below p. 14) is that it comes from a horizon close to the top of the Permian. The shoot *Voltziopsis angusta* comes from the Gosford Formation, at the top of the Narrabeen Group; also of Lower Triassic age. Taken together these arguments render a Lower Triassic age for *Voltziopsis* more likely than any younger age.

(3) *Generic Comparison.* The cone units of *Voltziopsis* are unlikely to be confused with anything else; the various genera at one time grouped with it are now known to be quite different (Florin 1944). The dimorphic foliage is also unusual, as is to a less extent the leaf shape and stomatal distribution as they are interpreted. Dimorphic foliage, of rather a different sort and based on a system of long shoots and foliage spurs, is seen in some *Voltzia* species (Schimper and Mougeot 1844, Schimper 1869, Brongniart 1828), but the cuticles of these shoots are unknown, Kräusel (1943) figures a cuticle as *?Voltzia*; it is quite different from *Voltziopsis*. *Swedenborgia* Nathorst (Harris 1935, Florin 1944) has a structure basically like that of *Voltziopsis*, but with a small, simple bract adnate over most of its length to the cone scale. *Rissikia* (see first of these notes) is slightly similar in its cuticle, but has bilaterally flattened leaves, and usually, lappetts or papillae over the stomata. *Walkomia* Frenguelli *non* Florin is discussed below. Among Permian conifers *Walkomiella* and *Buriadia* Seward and Sahni (see Florin 1944) are very different in leaf shape and (*Walkomiella*) cuticle and cone scale. *Paranocladus* Florin (1944) could be compared in its stomatal arrangements, but differs in its branching pattern, leaves, and in being more or less equally amphistomatic. *Voltziopsis* thus shows little if any approach to the southern Permian conifers.

Voltziopsis africana Seward

Pl. 1, A, D. Figs. 1A; 2A, B, D, E; 3B, D; 4A; 5A-C; 7D.

1899 *Voltziopsis* Potonié, pp. 303-304, fig. 304. Shoot and cone unit, latter taken as holotype. E. Africa.

FIG. 3.—*Voltziopsis africana*, B, D; *V. wolganensis*, A, C, E, F; pollen associated with *V. wolganensis*, G. A: Part of a cone unit seen from the abaxial side, showing part of the bract. C: An isolated unit, seen from adaxial side, the leftermost lobe outlined from the counterpart of this specimen. E: Part of a cone unit showing pointed lobes of the cone scale. F: A cone unit attached to the cone axis, seen adaxial view (note, lobes not all inserted at quite the same level). All x 7. F 2260. B, D; fragments of cuticle with a stoma, probably from leaf lower surface, x 200 and x 400. F 22426. G, A grain in rotated proximal polar view. x 600. F 2260.

1900 *Voltziopsis* Potonié: Potonie, pp. 503-504, fig. 29, a-g. Material as above.

?1922 *Voltzia* sp. Seward, pl. 17, figs. 8 and 9 only. Very fragmentary material, Tanganyika.

?1927 *Voltzia* sp. Gothan, p. 151, pl. 19, fig. 13 a, b. Obscure cone units.

1934 *Voltziopsis africana* Seward, p. 388, pl. 19, fig. 4 (cone unit), pl. 19, fig. 5 and pl. 20, fig. 9 (shoots). Tanganyika, ? from several localities.

1935 *Voltzia heterophylla* Carpentier non Brongniart, pl. 4, fig. 7 (shoot), pl. 5, figs. 8, 10, 11 (cone units), ? pl. 1, fig. 6 (shoot).

?1935 *Brachyphyllum* sp. Carpentier, pl. 1, fig. 3.

1936 *Voltzia heterophylla* Carpentier non Brongniart, pl. 5, figs. 9, 10. Carpentier's material from Madagascar. Excluded are 1935 pl. 1, figs. 4, 5, 7; pl. 2, figs. 12, 13; pl. 5, figs. 9, 12, 13.

1940 *Voltziopsis africana* Seward: Florin, pp. 57-58. Discussion.

1944 *Voltziopsis africana* Seward: Florin, pp. 486-488, pl. 181-182, figs. 3-5, text-fig. 53. Redescription of Potonié's material, with extended discussion.

Holotype: Potonié, (1899) fig. 304 (cone scale).

Locus typicus: In the vicinity of Tanga, E. Africa; Triassic, probably Lower Triassic.

Diagnosis (emended). Shoots sparingly branched, leaves only slightly dimorphic, wide, nearly flat, generally with obtuse apex, varying from 3 mm. long and 3 mm. wide and very obtusely pointed, to 7 mm. long and 2-4 mm. wide, bluntly pointed. Leaves generally borne all round shoot, but sometimes standing out at up to 90° from axis, and rarely slightly twisted to lie in two rows.

Shoot cuticle thin but tough, 1.5μ and 1μ, showing cells on both surfaces of rectangular to somewhat irregular shape, and often cell rows very obscure or absent. Cells about 54μ in length and 34μ wide, of wall thickness 6μ. Stomata few and scattered on thicker (lower) leaf surface, and usually with four subsidiary cells, two lateral and two terminal, and no encircling cells. On thinner (upper) leaf surface stomata scattered, or in obscure rows, with one to five epidermal cells between subsidiary cells of adjacent stomata, or in groups of 3-5 having subsidiary cells touching. Stomata monocyclic or, less often, irregularly dicyclic, subsidiary cells (on upper leaf surface) tending to form ring of 4-6 more or less wedge shaped cells of equal size.

Seed cone units 10-17 mm. long and 10-14 mm. wide; bract about 19 mm. long, forked in its last third, contracting to 1 mm. broad below; cone scale consisting of five (rarely six) lobes, cone scale 2-4 mm. wide below, lobes rounded at apex, 4-6 mm. from apex to point of union with other lobes, and about 3 mm. wide at maximum. Seed probably inverted, (?) about half as long as free lobes. (paraphrased from Florin 1944, pp. 486-487, but seeds now described as probably inverted not upright).

Description and discussion. Voltziopsis africana is a rather uncommon component of the Bulli roof shales flora. I have found it sparingly at Nattai Bulli, Oakdale and as fragments at South Bulli, Bulli and South Clifton. In the Mitchell collection in the Australian Museum there is another specimen, F22426, localised by Mitchell as coming from Wonoona Park [*sic.*]. This locality is almost certainly wrong, for this place, now Richardson Park, Woonona, lies on stabilised dune, at the level of the extreme base of the Coal Measures. Further, the associate is another conifer known only from the Bulli roof shales. Of course, Mitchell may have found the specimen in the fill, when the park was laid out.

No branching specimen has been seen, but it would seem from F22426 that branching is sparse. Indeed, it is possible that this piece did branch where it takes a sharp bend to the right, but there is no clear evidence that it did. In this species, as in the others, the impression of the upper leaf surface, around which the leaf is supposed to have collapsed, is convex; thus the leaf surface was concave (Fig. 2D), though in many cases the leaf is very nearly, or entirely, flat. As in the other species also, the margin is thin, but not scarious. On some specimens some of the larger leaves lie out at nearly 90° to the axis, and some of them are twisted in such a way as to bring the leaf surfaces parallel with the axis (Fig. 2D at top). They thus show the same sort of twisting as is seen in the larger leaves of *V. wolganensis* and is very common in the conifers, bringing the leaves apparently into two rows. On the other hand, other shoots present the leaves edge on (Fig. 2E). As in Figs. 2A, D the leaf apex may be either blunt or acute, generally more acute in the larger leaves. Fig. 2A shows an apex surrounded by a cluster of leaves, suggesting that the shoot was of unlimited growth.

The cuticle is more easily prepared, in my material, from Nattai Bulli and (especially) Oakdale than from the localities on the coast, where material is rather metamorphosed. The two sorts of cuticle are shown in Pl. 1D, indicating that except for a difference in thickness, in this species the two surfaces are extremely alike; while Fig. 5A, including a length of the margin, shows that the wrinkling found in the other species may be absent, suggesting that the leaf is flat. Where the stomata are fairly close set on the upper leaf surface the cells are scarcely in rows at all. (Pl. 1D, Fig. 5B), the arrangement of the stomata varying considerably even on the same leaf, from grouped (Fig. 5B) to scattered (Pl. ID). Likewise the arrangement of subsidiary and encircling cells varies the commonest sort seen being the sort in Fig. 7D. The stomata themselves, on the other hand, are rather uniform and extremely like those of the other species. As in them, the cuticle is entirely devoid of papillae or sinuosities of the cell outlines, though in the more battered pieces of cuticle it sometimes looks as if the cell outlines had holes in them. This is probably sand damage.

The shoots from New South Wales are not, so far, associated with *Voltziopsis* cone units. They are referred to *Voltziopsis* because of their close resemblance to *V. wolganensis* with its cone. The type material of *V. africana* (Potonié 1899) is badly preserved, but shows a shoot with leaves about the same size as mine, and of a similar shape, though some may be more acutely pointed than is usual. In the later material (Potonié 1900), shoots are figured showing foliar dimorphism just like mine. These resemblances are held to justify identification.

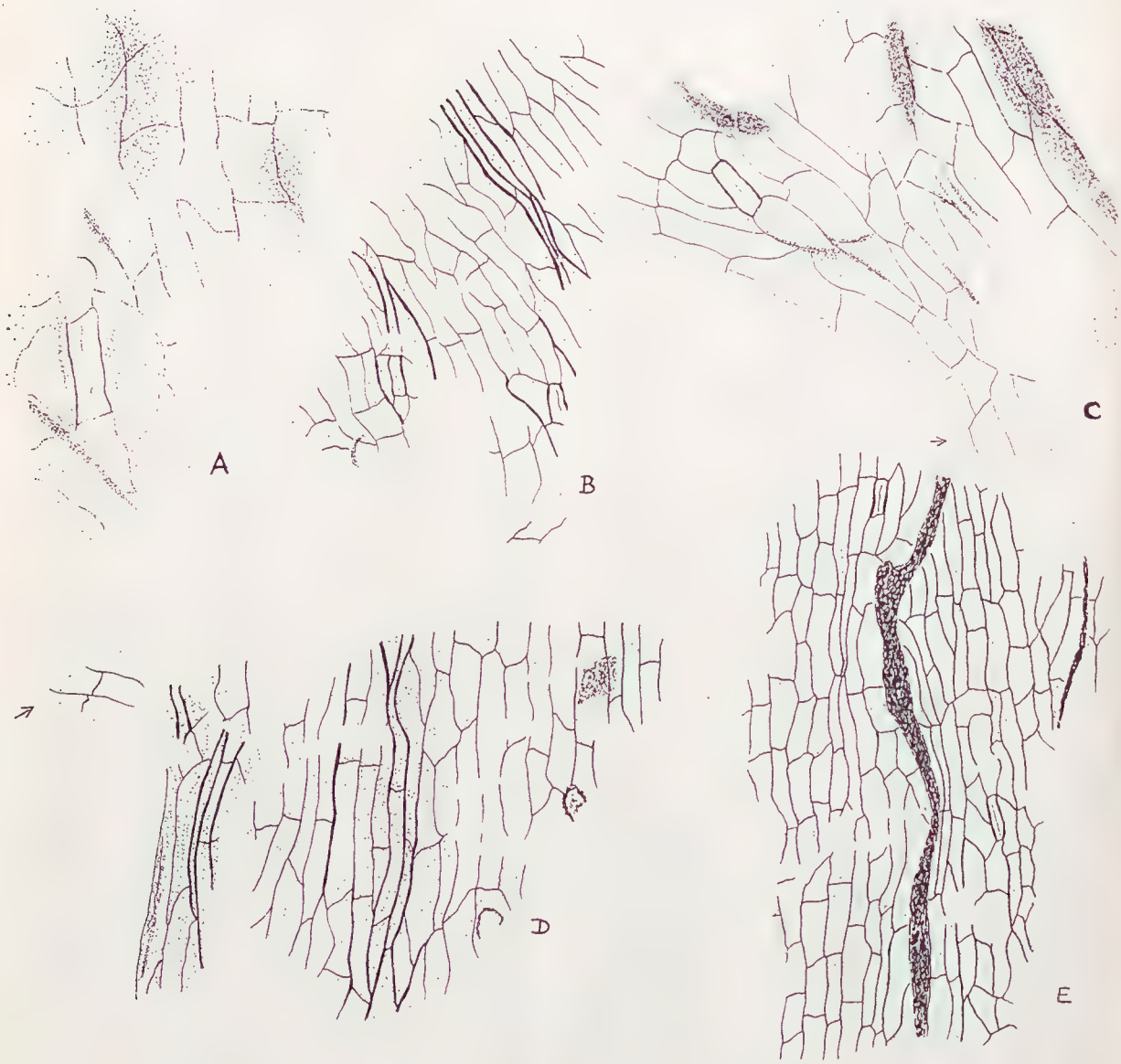

FIG. 4.—*Voltziopsis africana*, A; *V. wolganensis*, B-E. A: Fragment of cuticle with stoma x 600. B, D; Cuticle from cone scale, B upper surface joining onto D at arrow. x 200. F 2260. C: Cuticle from bract, ? of adaxial bract surface. x 200. F 2260. E: Cuticle from leaf lower surface. x 200. F 2260.

Seward (1934) and Florin (1944) confined the name *V. africana* to the cone units; it is now extended again to cover the shoots on circumstantial, but fairly impressive, evidence. First, cone units of *Voltziopsis wolganensis* are attached to shoots so similar to the isolated shoots of *V. africana* that distinguishing them is not always easy. Second, cone units and foliage are found associated in four or five localities in Africa and Madagascar (Potonié 1899, 1900; Seward 1922, 1934; Gothan 1927; Carpentier 1934, 1935), though not yet in Australia.

The diagnosis of the cone is based entirely on Florin's (1944) account, except that the seeds are considered even in this species to be inverted. Some figures of certain units (e.g. Florin 1944 Pl. 181-182, fig. 4 (lobe to right) and especially Carpentier 1935 Pl. 5 figs. 10, 11) show a line crossing the proximal parts of the lobes of the seed scale in just the way that the micropylar end of the seed in *V. wolganensis* does (Fig. 3F). Florin admitted that the point was uncertain (p. 487), and it is not now settled, though Florin's reconstruction has been copied without his hesitation (Schweitzer 1963).

Voltziopsis wolganensis sp. nov.

Pl. 1, figs. 2C; 3A, C, E, F; 4B-E; 5D, E; 6D; 7E.

1934 *Voltziopsis* Seward, pl. 20, fig. 10. Single shoot, from E. Africa.

1935 *Voltzia* cf. *heterophylla* forma *brevifolia* Carpentier, pl. 4, fig. 3, ? fig. 5, pl. 5, fig. 3 (*Voltzia* sp.) and ? fig. 2 (*Phyllotheca* sp.) shoots from Madagascar.

Holotype. F. 6620, Geological and Mining Museum, Sydney, Pl. 1, fig. E.

Locus typicus. Constance Gorge, near Newnes, New South Wales; Triassic ? Lower Triassic.

Diagnosis. Shoot system showing branches departing at 35°-45° every 15 cms. approximately; cone terminal on a short branch about 2 cms. long. Leaves of very varied sizes, when short, more or less triangular, appressed to stem, about 1 cm. long and 3 mms. wide, grading over into long leaves, 3 cms. long, 3-4 mms. wide. Leaves 2-3 mms. thick (compressed laterally). Upper leaf surface only slightly concave, and rarely raised over midline. Leaf apex more or less acute.

Cuticle on lower leaf surface showing more or less elongated rectangular cells about 41μ x 31μ, with occasional stomata, probably about 5/mms.^{2}. On upper surface cells over midline square or polygonal, about 45μ in diameter, showing irregular rows of stomata. In the rows stomata normally orientated longitudinally, and usually monocyclic, with 4-6 (mostly 4) subsidiary cells consisting of two lateral members, sometimes divided, and two terminals. In stomatal rows stomata separated by two terminal subsidiary cells, or by an encircling cell in addition; laterally 1-3 files of epidermal cells between two stomata.

Seed cone conical, about 2.5 cms. long and 1.5 cms. wide at maximum. Bract of cone unit forked in about last third of its length, as long as to be twice as long as cone scale. Five lobes of cone scale joined into stalk about 3 mms. long, each lobe about 4 mms. long, bearing single inverted seed about 2 mm. from apex. Apex of lobes acute, lobes 1.5-4 mms. wide. Cuticle on cone unit showing cells set more or less in rows, about 58μ x 30μ; stomata monocyclic or only rarely incompletely dicyclic, otherwise as on leaf. Seeds 1.5 mms. long and 1.0 mm. wide, fused seed stalk showing as a slight ridge about 0.25 mm. wide.

(i) *Description and discussion*: The material consists of a single specimen, F6620, in the Geological and Mining Museum, and I am most grateful to the Director of the Geological Survey of New South Wales and Dr. J. Pickett for allowing me to examine the specimen.

The locality is given as Constance Gorge. Unluckily two places have held this name. At present it is applied to a small gorge leading S.E. into Rocky Gorge and thence into the Wolgan River some five miles *downstream* from Newnes. Dr. Pickett and I walked through this system of gorges without finding anything the slightest bit hopeful. However, earlier, the name Constance Gorge was applied to an even smaller gorge (communicating, by one of the very few practicable passes through the sandstone walls confining the Wolgan Valley, with the present Constance Gorge) running W. into the Wolgan 2 miles *upstream* of Newnes. The sidings of the old Newnes Railway lay in this earlier named Constance Gorge and my guess is that the specimen was found during the building of the Newnes Railway, a work involving extensive excavation. The whole countryside is still only sparsely settled and very difficult. This matter is of importance, for if the specimen comes, as I suspect, from the earlier named Constance Gorge, it is definitely Lower Triassic, but if from the valley now holding the name, it may be either Lower or Middle Triassic (Hawkesbury). In this area both Narrabeen and Hawkesbury are very unfossiliferous.

There is some suggestion that small leaves alternate regularly with long ones (Pl. 1E), and just possibly this may be seasonal, for a slightly comparable variation in leaf length can be seen over a year's increment in *Podocarpus ferrugineus* Bidwill, and doubtless others. The leaves, however, are much the same shape whether long or short (Pl. 1E and Fig. 2C). Judging from the form of the compressed leaves, the upper surface was only slightly concave, and in a few places, when the leaf is compressed laterally, shows a low keel over the midline (Fig. 2C). The venation is unknown, as in all species.

The form of the cuticle is given in the diagnosis and in Figs. 4, 5 and 6. As with all species, the material breaks up into small pieces on maceration. It is not known whether there was a non stomatiferous zone over the midrib or not. In Fig. 6D to the left there appears to be an area devoid of stomata, and since the fragment comes from the central parts of the leaf this may represent a "midrib". In no stoma can one see any sign of papillae or lappetts.

The cone is attached by a short length of branch, with leaves just like any other (Pl. 1C). On the cone the bracts are strongly decurrent, but at the level of the cone scale, which emerges at about 90° from the main cone axis, turn out (Fig. 3F). It is difficult to see the bract on the cone, and its form is only clearly seen on the isolated cone unit in Fig.

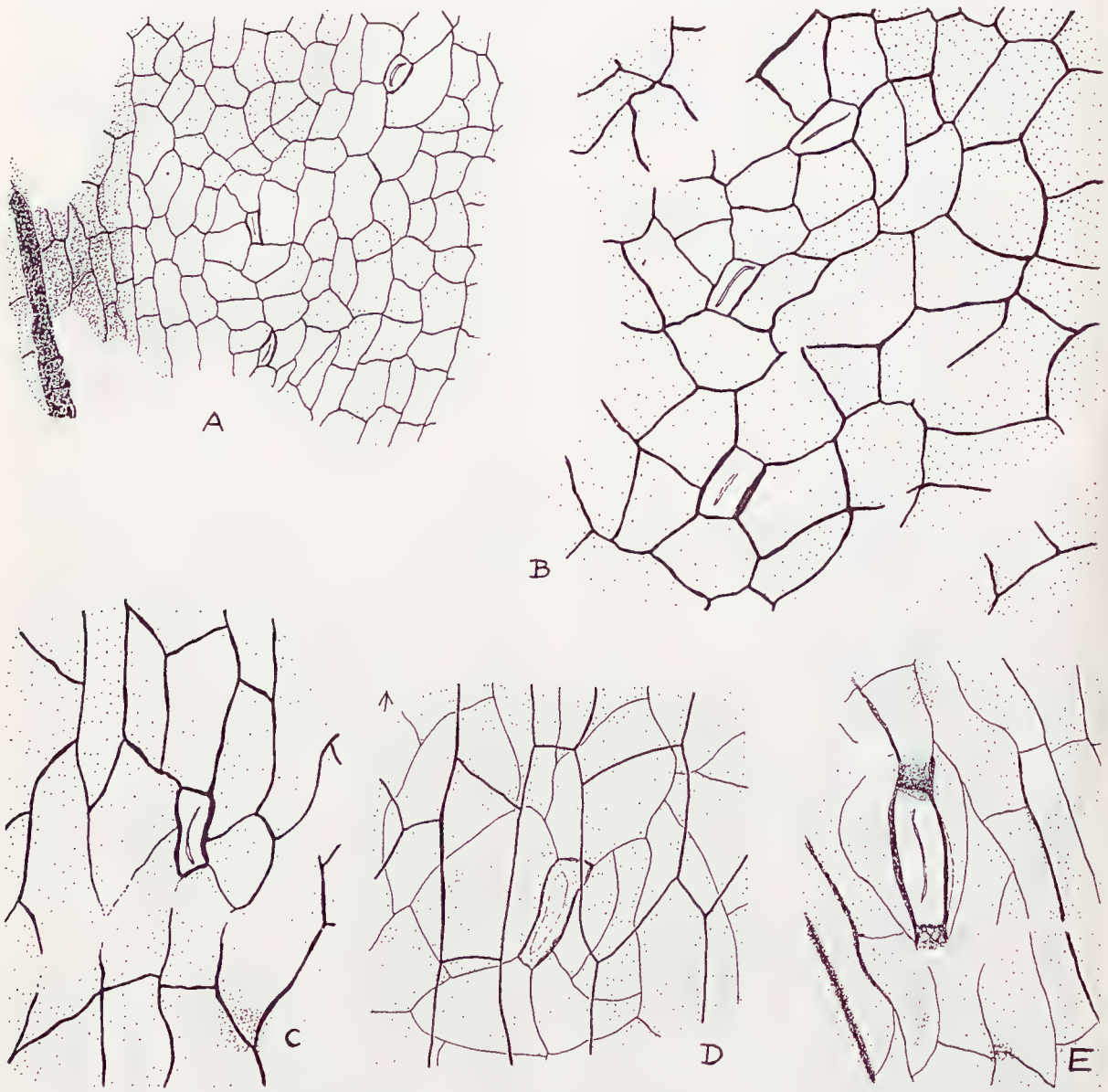

FIG. 5.—*Voltziopsis africana* A-C; *V. wolganensis* D, E. A: Cuticle towards margin of a leaf. x 200. 3001. B: Cuticle with three stomata with subsidiary cells touching. x 400. 3001. C: A stoma with rather few subsidiary cells. x 600. 3000. D: Cuticles from the cone scale, stoma present on one. x 600. F 2260. E: Stoma from leaf. x 600. F 2260.

3C, but several pieces show what is probably its forking end. Much of the same difficulty applies to the cone scales. In this material, however, only units with five lobes have been seen. The apex is most usually more or less acute (Fig. 3E), but in some it is more obtuse. The cone cuticle has already been discussed, and is shown in Figs. 4B, D.

(ii) *Note on associated pollen.* In two preparations pollen was found sticking to the cuticle of the leaf in groups, of three grains, and of two very badly preserved ones. So far as I can tell all is of the same sort.

The grains are disaccate, about 150μ in total width, with a corpus about 120μ wide and 120μ long. The grain in Fig. 3G is interpreted as a slightly rotated lateral longitudinal view, for it shows the striae towards the proximal (as interpreted) end of the grain, on both surfaces, but not at the distal. This specimen is slightly torn at the cappula, but shows that there was no colpus. The sacci are attached by heavily staining roots, and project slightly distally, and in the specimen figured are not continuous with one another (pseudo-monosaccate), but they are in another grain. The ornament consists of the usual recticulum on the sacci, perhaps with the muri somewhat radially disposed.

The corpus is round or oval in polar view, but slightly narrower at the cappula than the cappa (Fig. 3G), and its edge is taken to be marked by the strong line just inside the saccus roots. The striae are seen as very fine sometimes anastamosing grooves; twelve and ten are visible on the two best grains. In the grain figured the central stria is flanked by two rather heavy exinal thickenings, but in another grain, compressed laterally, all striae are alike (cf. the variations in the monolete mark of *Rissikia*).

There is no distinct evidence that these grains belong with *Voltziopsis*, but when one finds an extremely rare fossil associated with some rare pollen (Balme 1963) *set in groups*, the possibility is raised that the two belong together (cf. Harris 1964, pp. 176-178).

The grains are extremely like, though larger than, the grain named *Striatites sp.* cf. *Taeniaesporites antiquus* Leshik of Balme (1963, p. 26, pl. 6, fig. 13), which comes from the lowest Triassic (Kockatea Shale) in Western Australia. It also resembles the grains now named *Stroterporites richteri* Klaus and *S. jansonii* Klaus (1963), as Balme says. These grains show an especially prominent central stria, sometimes bifurcating (Klaus 1963, pl. 15); and it is believed that one of my grains showed a similar structure (above, and Fig. 3G). However, two other grains definitely do not show such a large stria. The point can be taken no further without more material. I do not think it would help to formalise these grains with a binomial and it is not clear what genus they should go into (cf. Hart 1964, pp. 1181, 1186).

(iii) *Specific comparisons. V. wolganensis* is distinguished from *V. africana* on three grounds. Its leaves are more dimorphic, longer and narrower than those of *V. africana*, while the stomata are mostly surrounded by only four subsidiary cells divided distinctly into lateral and terminal members, and not, as in *V. africana*, surrounded by a ring of subsidiary cells (Figs. 5B; 6D). However, there are intergrading leaves and many intergrading stomata, and I imagine that the distinction will only be really clear in good material. In addition, the lobes of the seed scale complex are more or less acute in *V. wolganensis* but obtuse in *V. africana*, though here too there are vexing intermediate cases (e.g. Carpentier 1935, pl. 5, fig. 10).

Voltziopsis augusta (Walkom) comb. nov.

Figs. 1B-D; 2F; 6A-C; 7A-C.

1922 *Ullmannia* sp. Seward, pp. 389, figs. 2-5. From Tanganyika.

1925 *Brachyphyllum angustum* Walkom, p. 221, pl. 30, figs. 5, 6.

1940 *Brachyphyllum angustum* Walkom: Florin, p. 49. Review only.

1944 *Walkomia primula* Frenguelli, pp. 300-306, pl. 5, figs. 1-5.

Holotype: Walkom 1925, pl. 30, fig. 5, the branched shoot to left.

Locus typicus: Turimetta Head, New South Wales; Gosford Formation, Upper Narrabeen Group, Lower Triassic.

Diagnosis emended. Sparingly branched shoots having short leaves about 3 mms. long (minimum) and 3-4 mms. wide, varying up to long leaves 1 cm. long, of same width. Leaf upper surface only slightly concave, but no sign of keel over "midrib" seen. Leaf 1.2 mms. thick (compressed laterally). Leaf apices more or less acute, margin thin but not scarious.

Cuticle on lower leaf surface 1.5-2μ thick, showing more or less square to slightly elongated cells, running in rows. Cells about 35μ across. No stomata seen on undoubted lower leaf surface. Cuticle on upper leaf surface at margins as on lower surface, margins about 8 cells wide. Elsewhere cells more or less square, about 40μ across, but less regularly in rows. Stomata scattered, or lying distant from one another in vague rows. Stomata with longitudinal to (more often) irregular orientation, mono, or dicyclic, subsidiary cells 4-8 (mostly 5 or 6) forming a ring and not always separable into lateral and terminal members. Surface of subsidiary cells smooth, and encircling cells quite unspecialised except by position. Stomata separated by at least 2 or 3 epidermal cells. Guard cells somewhat sunken in rounded pit, about 25μ in diameter, subsidiary cell ring sometimes slightly sunken. Guard cells feebly cutinised except round aperture. Cell outline on lower surface 3-6μ thick, on upper 2-6μ, neither showing sinuosites, processes or pitting.

Description and Discussion. The material examined consists of three short lengths of shoot on one block (F13022), and two fragments on a second (F13021). Both are unlocalised but F13022 almost certainly comes from Turimetta Head, since it is in a collection some of which was definitely localised as Turimetta by Walkom (1925); and the matrix looks indistinguishable from material I have collected at Turimetta. I have failed, however, to rediscover this conifer. F13021 is not from Turimetta, but, again judging from the matrix, may have been discovered (along with a good many

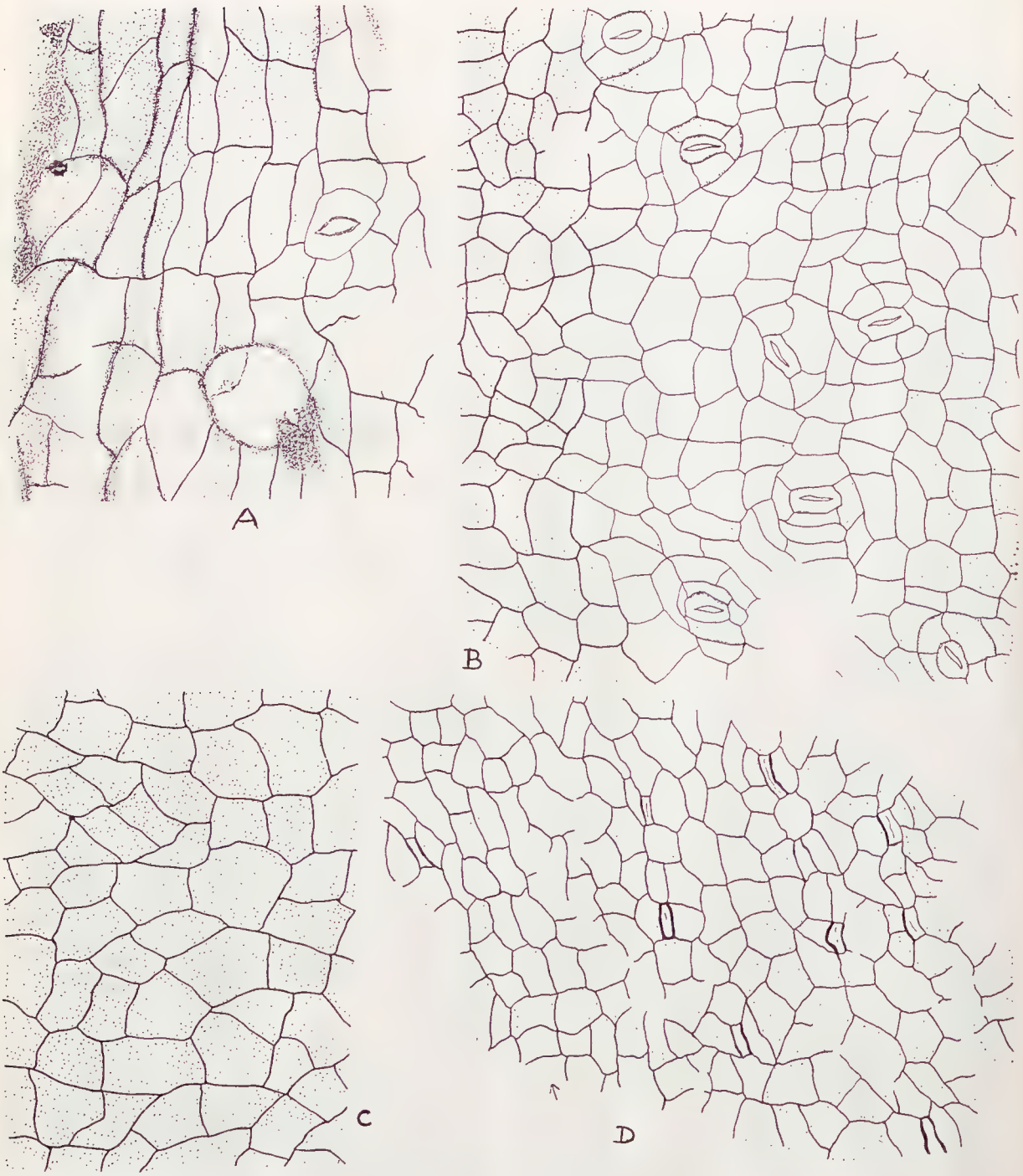

FIG. 6.—*Voltziopsis angusta*, A-C; *V. wolganensis*, D. A: thick cuticle, probably from leaf lower surface, and a stoma. x 400. F 13022. B: Cuticle from upper leaf surface, heavier stipple to left taken to mark midrib. x 400. F 13021. C: Cuticle from leaf lower surface. x 900. F 13022. D: Cuticle from leaf upper surface, arrow marking position of possible midrib. x 400. F 2260.

other fossils) when the swimming baths at Narrabeen were dug. Walkom's (*loc. cit.*) specimens are neither in the Australian Museum, nor the Geological and Mining Museum, nor in either University collection. They seem to be lost.

The leaves are shown in Figs. 1 and 2. They display the same sort of dimorphism as *V. wolganensis*, but less extremely. Even the long leaves are directed forwards, and show no sign of twisting into two ranks. Normally parts of four leaves can be seen in any place on a stem (Figs. 1B, 2F; Fig. 2F at a branch), but on some of the smaller pieces only three may be visible (Fig. 1C). The leaf shape in section is reconstructed as in *V. africana* (see above, p. 179). As in that species, the leafy margin is thin, but not scarious and shows in some cuticle preparation wrinklings of the sort seen in Fig. 4D.

In the cuticle preparations in which both surfaces could be associated, or followed through maceration, no stomata at all could be found in the thicker (presumably lower) cuticle. In one place, however, (Fig. 6A) there is a somewhat substantial cuticle, showing one stoma, and this may be from the lower leaf surface. The probability is (on the assumption already discussed as to the orientation of the cuticle fragments) that the leaf was entirely or almost entirely epistomatic. Stomata are less commonly met with in preparations from long leaves, and it is possible that, within limits, the number of stomata is fixed per leaf, but more material is needed to confirm this speculation.

The cells and cell outlines are shown in Figs. 6 and 7. The stomata are most varied. At one extreme (Fig. 6D) there are no encircling cells, and the stomatal apparatus comes close to *V. wolganensis;* at the other (Fig. 7C) the stomata is more or less reguarly dicyclic. However, in all seen the pit is rounded rather than rectangular, and the subsidiary cells do not usually fall easily into terminal and laterals. Judging both from focussing, and from differences in shade, the whole circle of encirling cells may be sunken slightly.

Except for the possible difference in stomatal density, the cuticular details of all the shoots, as well as the leaf shape in section, is the same. Thus only one species is present. It is most unfortunate that Walkom's specimens are lost especially as the description given is uninformative. Judging from dimensions, and from the figures, there are no differences between Walkom's material and mine, unless it be that Walkom's shoots are rather smaller (e.g. his Pl. 30, fig. 6), but this seems to be matched (Fig. 1C). As noted, part of my material is probably from Turrimetta, which was Walkom's locality. On these grounds, I identify my material with Walkom's.

Walkomia primula Frenguelli (1944) is another difficult case, for again the description lacks detail. It is identified because, on evidence available at present, the differences between it and the New South Wales material are slight. Dimorphism of the leaves is not mentioned, but some would seem to be present (see Frenguelli 1944, pl. 5, figs. 3, 4, 5); certain specimens may be narrower, than the normal, but they can be matched, at least to some extent (Frenguelli 1944, pl. 5, fig. 4 and Fig. 1C). The leaves of *W. primula* are narrower than usual, but so they are in Fig. 1D. Until cuticular detail is known there appears to be no grounds for maintaining *W. primula* as a separate species. However, the cuticle of Frenguelli's specimens has not been examined. The name *Walkomia* was misapplied by Florin (1944, p. 370, footnote). This is of no consequence if, as seems probable, *Walkomia primula* is identical with *Voltziopsis angusta.*

Seward's (1922) material lacks detail, but in what can be seen it agrees closely with *V. angusta,* and is therefore separated from *Ullmannia,* with which agreement is not very close, and identified with *V. angusta.*

The reason for placing *V. augusta* in *Voltziopsis* is that in its leaf shape and cuticle it comes extremely close to the two species of *Voltziopsis*

TABLE I.

Comparison of Voltziopsis species

	V. africana	*V. wolganensis*	*V. angusta*
Leaves	Up to 1 cm. long, 5 mms. wide apex obtuse; slightly twisted into 2 ranks	Up to 3 cms. long, 3-4 mms. wide, apex acute, when large twisted into two ranks	Up to 1 cm. long, 2-3 mms. wide, apex acute, never twisted into 2 ranks
Stomatal distribution	Unequally amphistomatic, stomata ± in rows	Unequally amphistomatic, stomata ± in rows	Almost or quite epistomatic, stomata set irregularly
Subsidiary and encircling cells	Stomata mostly monocyclic, rarely incompletely dicyclic subsidiary cells often forming ring of 4-6, but not sunken	Stomata mainly monocyclic, subsidiary cells mostly four, and not sunken	Stomata mostly incompletely dicyclic, subsidiary cells set in a ring, often slightly sunken
Cone scale	Lobes obtuse, bract not much longer than cone scale	Lobes acute, bract (when seen) notably longer than cone scale	NO INFORMATION

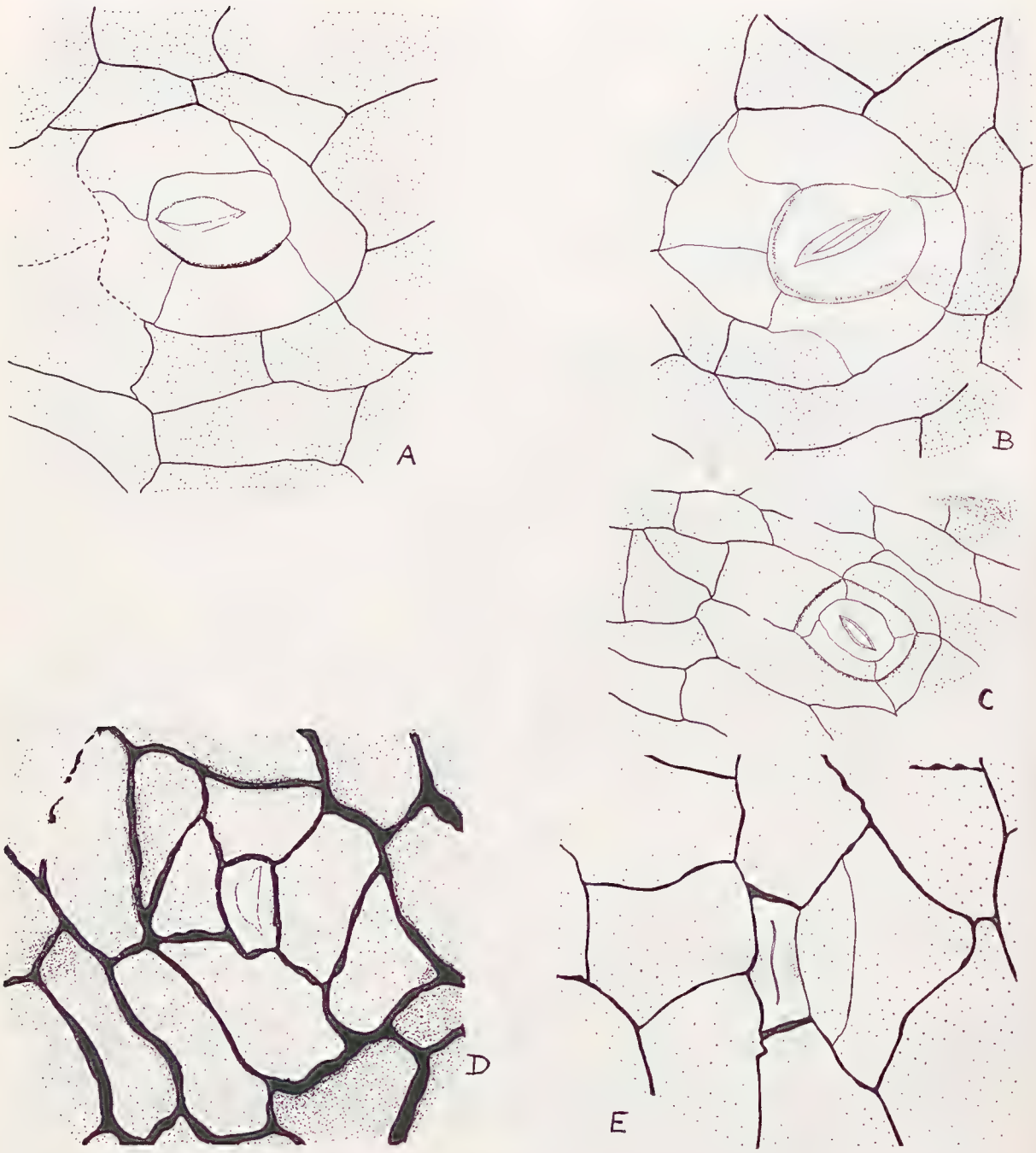

FIG. 7.—*Voltziopsis angusta*, A-C; *V. africana*, D; *V. wolganensis*, E. A-C: Stomata, A from a long leaf, partly dicyclic, B from a short leaf, C from a short leaf, monocyclic. A, B x 600, C x 400. F 13022. D: A stoma, partly dicyclic, with subsidiary and encircling cells tending to form a ring (cf. Fig. 5A.) x 600. 3001. E: A stoma of the sort most often seen, and with one subsidiary cell divided. x 600. F 2260.

known with cones. It is slightly younger than either of the others, but occurs in the same region, and in a similar flora. The situation is therefore just like that in which leaves of, say, *Athrotaxis* from the Australian early Tertiary are ascribed to a living genus, and the evidence somewhat stronger than that for ascribing Tertiary conifer shoots to *Metasequoia* when they come from regions where *Metasequoia* is not now found. A further reason is that Seward (1922) found seed cone units rather like *Voltziopsis* with his material.

The three species of *Voltziopsis* may be compared as below (Table I).

GENERAL DISCUSSION

As here interpreted *Voltziopsis* is a genus of conifers, having shoots all of one sort, dimorphic leaves, triangular or crescentic in section, with a thin cuticle with somewhat scattered, not regularly alligned simple stomata mostly or (possibly) all on the upper surface of the leaf; with compact seed cones, having forked bracts and five-partite (rarely six-partite) cone scales, each lobe being adnate to the stalk of one inverted seed. These conifers are probably Lower Triassic. The chief lack is any knowledge of the pollen cone, though it is possible that the pollen corresponds broadly with *Striatosporites* Wilson (Klaus 1963).

With this information they seem to diverge sharply from nearly all other Upper Permian and Lower Triassic conifers, including the podocarpaceous *Rissikia*. The (isolated) cone most closely comparable is *Swedenborgia* Nathorst (see Harris 1935), which has essentially the same construction (including the long stalk to the cone scale), differing only in the bract, which is small and adnate to the cone scale in *Swedenborgia* but free and forked in *Voltziopsis*. However, reduction in size and adnation of the bract to the cone scale is a general feature of conifer evolution, and I doubt whether this difference between *Voltziopsis* and *Swedenborgia* is of much significance. The foliage of *Swedenborgia* is not known, but Harris (1935) suggested that it might belong to *Podozamites*: if so, this would be a most important difference between the two conifers. It is of interest that the stomata of *Swedenborgia* resemble those of *Voltziopsis*, though their structure is so generalised that little weight can attach to this resemblance. Florin (1944) points out that *Swedenborgia* has essentially the same structure as the *Cryptomeria* seed cone, and could therefore stand close to the *Taxodiaceae*. The same argument may be applied to *Voltziopsis*, and some other facts are consistent with it. The leaf form of *V. wolganensis* and *V. angusta* is rather like that of *Athrotaxis selaginoides*, as is also the stomatal distribution. The arrangement of subsidiary cells recalls *Cryptomeria* (see Florin 1931) but not the stomatal arrangement which in *Cryptomeria* is in zones. The way in which the stomata of *V. africana* may lie in groups with their subsidiary cells touching recalls *Athrotaxis*, especially *A. laxifolia* Hook. though here the subsidiary cells may be shared, and in *A. selaginoides* there is only a single large group or mass of stomata covering most of the upper leaf surface. The irregular orientation of the stomata is seen in the Taxodiaceae, but in other places as well, e.g. *Araucaria*, where the subsidiary cell arrangement is different. If the associated pollen should prove to belong to *Voltziopsis*, this is an important matter, though not one that rules out a connection with the Taxodiaceae (cf. *Pinus* L. and *Larix* Mill.) The leaf dimorphism of *Voltziopsis* finds some but not a complete parallel in species of *Taxodium* Rich. and *Glyptostrobus* Endl. (Florin 1931 pls. 6 and 7.)

I do not place *Voltziopsis* in the Taxodiaceae, believing that unless we have foliage and both sorts of cones agreeing with, or explicable in terms of, a living family, such an ascription is premature. We have as yet no right to assume that the Triassic conifers all belonged to the families now living, though they may ultimately prove to do so (cf. *Cherolepidium* (Schimp.) Takhtaj.). The Family Voltziaceae (Pilger and Melchior 1954), an assembly of diverse fossils, provides a convenient resting place for the moment.

Schweitzer (1963) has carefully re-examined *Pseudovoltzia* Florin, and while confirming Florin at most points, shows that this genus generally has two seeds only per cone scale, not three. He proceeds to argue that the majority of conifers can be derived from *Pseudovoltzia*. In the sense that very many conifer cones can, by what Bower once called a morphological *tour de force* be derived from *Pseudovoltzia*, this is true. In the sense that any phylogenetic connection is likely, I reject the argument for *Voltziopsis* as for *Rissikia*. Evolution in the conifers at large, and in the Podocarpaceae and Taxodiaceae has in general tended to reduce the number of parts, and orders of branching. Scheitzer's view implies first an increase in number of seeds, then a decrease. This is complicated and unnecessary. Beside, there are considerable other differences between the cones, and so much as is known of the foliage of *Pseudovoltzia*, *Rissikia*, and *Voltziopsis*. *Pseudovoltzia* is Upper Permian in age, the others definitely date from the Lower, and probably basal, Triassic, and on palynological evidence may be even older, as old in fact as *Pseudovoltzia*. This, to my mind, does not give time for the complex evolution necessary.

Equally I can see no very obvious connections between *Voltziopsis*, (and *Rissikia*, see the first of these notes) and *Lebachia* Florin. Doubtless both derive ultimately from that complex of very early conifers of which *Lebachia* was a rather specialised member; but that would seem to be the whole extent of any connection.

The southern conifers, *Rissikia* and *Voltziopsis* suggest another view of conifer evolution, with which indeed, the known facts about the northern Triassic and later Permian conifers are consistent, though this view remains speculation.

Supposing that the conifer flower was originally radially organised, evolution proceeded, as Florin has shown, towards flattening and reduction of parts. In the podocarpaceae a trimerous symmetry seems to have resulted; in the Pinaceae (with which *Glyptolepis* Schimp. and *Pseudovoltzia* compare) we have only two "megasporophylls" but several sterile lobes; it is possible that in the Taxodiaceae, with which de Laubunfels (1965) would associate the Cupressaceae, as in *Voltziopsis* and *Swedenborgia*, five lobes each associated with a seed

is basic, other patterns occurring (e.g. *Cunninghamia* R. Br. with three lobes to the seed scale complex); while in the Araucariaceae, perhaps a single lobe and "megasporophyll" is basic, as it is in *Ullmannia* Goepp., though the cone scale details are different. There is at least some evidence for tracing each of the supposed lines of evolution into the Permian, and I suggest the possibility that each arose independently of the others, perhaps as early as the Carboniferous. This suggestion is far from original.

If the pollen associated with *V. wolganensis* does really derive from it, we have an interesting situation paralleling what is found in *Rissikia*. The pollen is known first from the Northern Hemisphere Permian, but, as far as is known, only from the base of the Triassic in Gondwanan areas (Balme 1963). This suggests, as Balme showed, that part of the early Triassic Gondwanan flora was immigrant from northern lands, these conifers perhaps being in that immigrant part.

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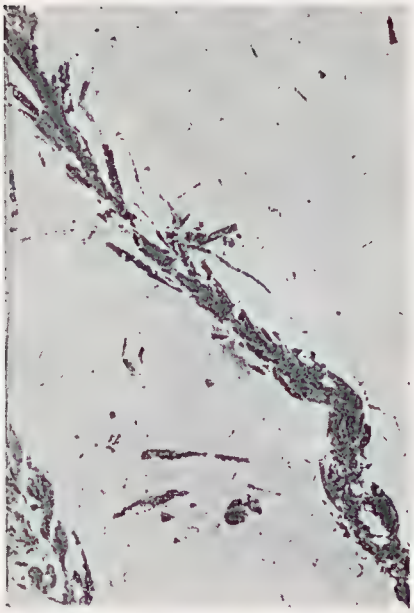
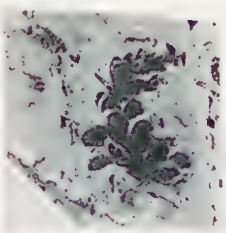
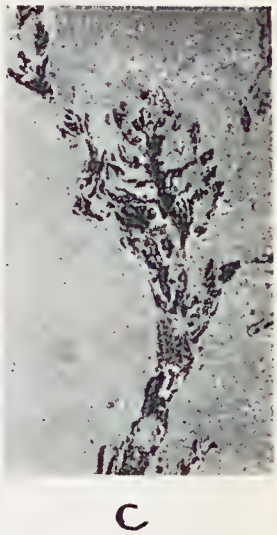
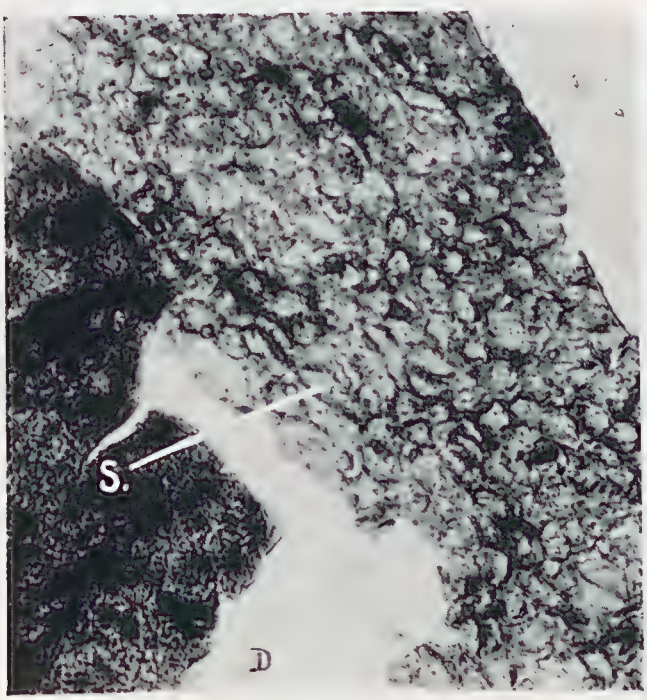








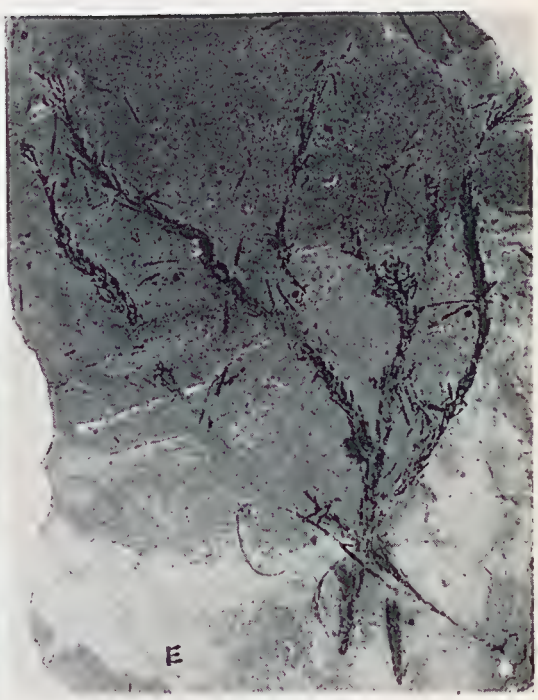


Plate I.—*Voltziopis africana* A, D: *V. wolganensis*, B, C, E. A: short length of shoot, x 1; 2968; B: Part of a shoot showing different leaf sizes, x 1; C: The seed cone attached to its branch, x 0.75; D: Cuticle from two leaf surfaces (upper to right), a stoma at *s* x 100, 3001; E: The whole specimen x 0.3. B, C, E, F 6620.

Papers and Proceedings of the Royal Society of Tasmania, Volume 101.

OBSERVATIONS ON SOME TASMANIAN FISHES: PART XV

By

E. O. G. Scott

(With three text figures)

ABSTRACT

A new Ophiclinid genus is established and its haplotype is described and figured. Two species are added to the Tasmanian list and the inclusion of one is confirmed. General observations, usually accompanied by a table of dimensions, are made on these and several other species (some points of special interest noticed below).

Secondary sexual dimorphism is found in several Ophiclinids, females having relatively longer trunk, with concomitantly greater value for the ratio of dorsal base to anal base. A second lateral line, hitherto unreported, has been observed in *Ophiclinus* Castlenau, 1872, *s. str.*, and a lateral line in *Ophiclinops* Whitley, 1932.

Rajidae.—*Raja whitleyi* Iredale, 1938: inclusion in Tasmanian list confirmed; several characters commonly relied on to separate this species from *Raja lemprièri* Richardson, 1845 found to be inconstant. Clinidae.—*Clinus perspicillatus* Cuvier & Valenciennes, 1836: frequency distribution of spines of second dorsal and frequency distribution of rays for each spine number both approximately symmetrical, suggesting separate genetic mediation of radial elements in two sections of fin (pigmentation also probably dual controlled); secondary sexual dimorphism parallels that of Ophiclinids. *Petraïtes phillipi* (Lucas, 1891): abnormal individual. *Petraites heptaeolus* Ogilby, 1885: parous at 44 mm; intromittent organ described. Ophiclinidae.—Key to Tasmanian species. *Ophiclinus aethiops* McCulloch & Waite, 1918: added to Tasmanian list; original account extended; present material (apparently the first reported since types) poses a question of the distinctness of this species from *O. gabrieli* Waite, 1906. *Ophiclinus greeni* Scott, 1936: anal spines 2, not 3 as originally reported; notes on a parous female. *Ophiclinus gabrieli* Waite, 1906: anal, reported as without spines, has 2; dentition; possible conspecificity with *O. aethiops* discussed; cephalic neuromast system described. *Ophiclinops varius* (McCulloch & Waite, 1918): metrical data. *Breona greeni gen. et sp. nov.*: described and figured. Tripterygiidae.—Key to Tasmanian species. *Brachynectes fasciatus* Scott, 1957: added to Tasmanian list; emendations to, and expansion of, original account.

Some notes are given on the catches at two surf angling contests.

INTRODUCTION

This paper follows the general plan of others in the series. Certain conventions are regularly observed: (*a*) *unit of measurement.*—where the unit of a length measurement is not stated, millimetre(s) is to be understood: (*b*) *standard deviation.*—whether for direct citation or in the computation of derived quantities (standard errors, coefficient of variation), 'ordinary' or unadjusted standard deviation, with division by n, not $(n\text{-}1)$, has been calculated, regardless of size of sample: (*c*) *locality.*—the county name is included in Tasmanian localities: (*d*) *sequence of specification.*—where 2 or more specimens are noted in the one context, the sequence of citation of the relevant specification is, where the sexes are not distinguished, that of increasing size of fish, as measured by standard length (rarely, if standard length is for any reason inappropriate, by total length), or, where the sexes are distinguished, by a similar sequence within the sexes: (*e*) *abbreviations.*—*Ls, Lt* denote standard length, total length, respectively; *TLs, TLt,* signify thousandths of standard, of total, length.

Family RAJIDAE

The Check-List carries only one Tasmanian entry, (*i*) *Raja lemprièri* Richardson, 1845 (type locality: Port Arthur [Pembroke], Tasmania), but admits two from Bass Strait (much of which is Tasmanian territorial water), (*ii*) *R. nasuta* Müller & Henle, 1841, (*iii*) *R. nitida* Günther, 1860. In the Handbook Munro (1956) admits as Tasmanian (*i*) and (*iii*), confining (*ii*) to Victoria: he adds (*iv*) *R. cerva* Whitley, 1939, (*v*) *R. whitleyi* Iredale, 1938. Earlier Whitley (1940) had listed for this State (*i*), (*iii*) (as *Pavoraja nita*) (*iv*), with (*ii*) (as *Zearaja nasuta*) from Bass Strait.

The only authority for the local occurrence of *R. whitleyi* appears to be Munro: Scott, writing later (1962) listed only New South Wales, Victoria, South Australia (the last an addition to the Check-List distribution). The appearance of this species on our list is confirmed by the specimens noted below.

In view of the fact that examination of this material shows that some characters commonly relied on—*e.g.*, in key by Scott (1962: 47)—to separate *R. whitleyi* (the nomenclature of which appears to have received more attention than have its external features) and *R. lemprièri* are not constant, it is perhaps inexpedient at this stage to key the Tasmanian forms. [Whitley (1940) has referred, further, to the occurrence of confusion between *R. whitleyi* and two other species, *R. dentata* Klunzinger, 1872 (for which he proposes the subgenus *Dentiraja*) and *R. ogilbyi* Whitley, 1939 (referred to the genus *Spiniraja* Whitley)].

Genus **RAJA** Linné, 1758

Raja whitleyi Iredale, 1938

Raja oxyyrhynchus Castelnau, 1872, *Proc. Zool. Acclim. Soc. Vict.*, 1: 244. *Non Raja oxyrhynchus* Linné, 1758.

Raja rostrata Castelnau, 1873, *Intercol. Exhib. Essays*, No. V (*Vict. Offic. Rec. Philad. Exhib.*): 17. Type locality: Melbourne, Victoria. Preoccupied *by R. rostrata* Lacépède.

Raia scabra Ogilby, 1888, Cat. Fish. Aust. Mus., 1: 17. Type localities: Manly, New South Wales, and Port Phillip, Victoria. Preoccupied by *R. scabra* Linné, 1764.

Raja whitleyi Iredale, 1938, *Aust. Zool.*, 9, 2: 169. Type locality: Port Phillip, Victoria.

Distribution.—Under the entry *R. scabra* Ogilby, the Check-List (McCulloch, 1929: 24) gives New South Wales, Victoria (type localities). Whitley (1940) admits only Victoria; while Scott (1962: 49) adds to the Check-List distribution South Australia; however, earlier, Munro (1956: 15) had listed Tasmania (along with New South Wales and Victoria). Specimens here noted serve to confirm the Tasmanian record.

Material.—The following observations are based on (*a*) a female, disc width 454; (*b*), (*c*), (*d*) 3 males, disc widths 455, 498, 603, caught at the Tasmanian Open Surf Angling Championships, Swimcart Beach, St Helens, Dorset, on 7th, 8th May, 1966 (see general notes on this meeting, below). Unfortunately, in accordance with the standard practice at such competitions, the tips of the tails were severed upon presentation of the fish at the check-point. At the conclusion of the contest the specimens were made available by the St Helens Surf Angling Club, and have since been handed over to the Queen Victoria Museum, Launceston (Reg. Nos. 1966/5/6-9).

Spines.—Throughout this section an entry consisting of three digits following a decimal point on the right of a zero denotes a linear measurement expressed as a decimal fraction of greatest disc width of the relevant specimen.

The number and arrangement of spines exhibit considerable variation, involving, in some cases, marked departure from standard accounts: attention is called to some of these divergences by quotation of the relevant passages in the treatment of the species in Scott's work on the fishes of South Australia (1962: 48-49, unnumbered fig. on p. 49). (*i*) 'Two sharp spines in the mid-line of the disc, behind the eyes': in (*a*) 1, stout, with broad buckler-like base 0.095 behind spiracles; in (*b*), (*c*), (*d*) 6, 3, 4, lying 0.070, 0.086, 0.099 behind spiracles, the series extending over 0.137, 0.035, 0.090. (*ii*) 'A row of six to seven spines on either side of the mid-line, at the posterior end of the disc': in (*a*), (*c*), (*d*) no spines here; in (*b*) on left 3 weak, 1st 0.700 from snout tip, series extending 0.077, on right none. (*iii*) 'The tail bears a median row of 11 to 12 spines between its base and the first dorsal fin': (*a*), (*b*), (*c*), (*d*) with 18, 23, 12, 10 spines (14, 15, 7, 10 of them fairly large), extending over 0.269, 0.396 (ending 0.048 in front of dorsal), 0.253, 0.367; this series beginning behind origin (on upper surface) of pelvic by 0.121, 0.044, 0.100, 0.075; in all our examples tips of tails are missing. (*iv*) 'The sides of the tail are armed with a single row of smaller spines' [the presence of this series is used in Scott's key (1962: 47) in distinguishing this species from *R. lemprièri* Richardson, 1845]: (*a*), (*b*), (*d*) have on left 10, 19, 13 spines, extending over 0.163, 0.305, 0.180, on right 11, 17, 11 spines, extending over 0.181, 0.297, 0.204; this series begins in (*a*) 0.011 behind, in (*b*), (*d*) 0.088, 0.041, respectively, in front of, level of freely lying pelvics; no spines on sides of tail in (*c*). (*v*) In (*b*) 1 spine barely in front of, just internad of, eye, 0.015 from orbit; in (*d*) on right, 2 spines, one on level with front of eye, 0.007 from orbit, the other 0.008 in front of this, on left 3 spines, hindmost on transverse level with orbit, 0.007 from it, next 0.005 in front of 1st, 3rd 0.005 in front of 2nd; in (*a*), (*c*) no spines near eyes [the absence of spines near the eyes in males is a feature used in Scott's key in separating this species from *R. lemprièri*; they are present in 2 of our 3 males]. (*vi*) 'The disc above and below is covered with small prickles, which are longer and sharper on the snout'; upper surface wholly covered, except (all specimens) outer part of small first lobe of pelvics, a marginal strip, 1-2 mm wide, on larger pelvic lobe, and in places along the margin of the pectoral; lower surface wholly covered back to, or somewhat beyond, level of maximum width of disc, behind which there is a bare subtriangular marginal strip, 0.055, 0.077, 0.060, 0.050 wide anteriorly, decreasing to, or almost to, zero at posterior end of disc, a marginal bare strip on pectoral, a bare area (reniform in (*a*), (*b*), (*c*), rectangular in (*d*)) at base of tail, its median anteroposterior extent 0.038, 0.066, 0.070, 0.056. (*vii*) In all specimens a median ridge, lying behind the region bearing the median spines noted for (*a*) in (*ii*), is rougher, and carries larger prickles, than the adjoining skin; best developed in (*c*), in which it begins 0.040 behind the 3rd median spine, and extends back through 0.351 to origin of supracaudal series.

Caudal ridge.—A pronounced white fleshy fringe runs along either side of the tail, extending the whole length of the appendage as preserved; in (*b*) it is less well developed posteriorly than anteriorly.

Coloration.—'Disc coloured slate grey above, white below, the upper surface and tail with irregular white spots and flecks.' The white spots are not recorded for *R. lemprièri*. In (*a*), (*b*), (*c*), (*d*) there are on each upper half of the disc upwards of 100, 30-40, about 30, 90-100 small spots or irregular splashes of white: on tail, in (*a*) 7-9 on each side, extending to present (mutilated) tip; (*b*) 2 on right, 1 on left lying 0.220 from dorsal origin of tail (tail is recognizable as an appendage more anteriorly above than below); (*c*) none; (*d*) 7-8 on right, 3 on left, extending back 0.003 from dorsal origin of tail.

Buccal processes.—The processes around the free posterior margin of the left nasal lobe of (*a*) number 15, well developed; in sequence from the inner side, 1 with 3 branches, 2 double, 1 single, 2 double, 1 single, 5 double, 1 single, 1 double, 1 single; followed by 6 barely developed, little more than a series of crenulations.

Proportions.—Some proportions, expressed as thousandths of the greatest width of the disc, are set out in Table I. As already mentioned, the tip

TABLE I

Raja whitleyi Iredale, 1938. Dimensions, expressed as thousandths of disc width, of 3 males and 1 female from Swimcart Beach, Dorset, Tasmania, 7th, 8th May, 1966

Dimension	Specimen (Sex; disc width, mm)			
	(*a*) ♀ 454	(*b*) ♂ 455	(*c*) ♂ 498	(*d*) ♂ 603
Width at front of eyes	520	495	494	484
Width at front of vent (across pelvics only)	233	308	247	282
Width at front of vent (across pectorals)	573	571	602	481
Distance behind snout tip at which disc width is twice that distance	26	30	24	111
Length to junction of disc and pelvics (upper surface)	729	765	755	748
Length to hind border of pelvics, as they lie	927	985	975	881
Total length	....	....	1400	....
Length to front of vent, length of vent	745, 42	785, 46	757, 40	756, 30
Length to front of eyes	229	232	230	234
Length of eye, width of eye	43, 30	46, 38	42, 28	36, 27
Interocular	85	97	86	91
Spiracle: length (anteroposterior), oblique width	15, 26	22, 29	22, 27	23, 30
Interspiracular distance (between inner borders)	107	110	111	116
Length to nostril	170	174	171	178
Nostril: oblique diameter of narial chamber, of external aperture	42, 12	44, 11	48, 12	40, 10
Internarial: between inner edges of narial basin, of external lobes	96, 151	97, 149	82, 153	90, 142
Length to free border of upper lip	207	202	211	208
Length to middle of anterior margin of upper tooth band	214	214	221	212
Exposed mesial anteroposterior extension of upper tooth band	18	16	16	17
Length to middle of posterior margin of lower tooth band	233	233	241	250
Exposed mesial anteroposterior extension of lower tooth band	13	11	16	13
Total width of tooth band: upper, lower	148, 139	136, 125	135, 122	145, 124
Width of mouth cleft	151	151	159	157
Distance between external borders of nasal lobes: maximum, minimum	159, 152	166, 147	165, 146	163, 147
Gill slits: lengths to slits	344, 368, 388, 407, 418	360, 385, 409, 431, 451	361, 386, 408, 428, 446	355, 380, 403, 423, 441
Gill silts: lengths of slits	22, 22, 20, 20, 17	22, 20, 18, 18, 16	30, 27, 22, 20, 16	30, 30, 25, 20, 13
Gill slits: distances between right and left slits	273, 253, 227, 187, 156	262, 248, 226, 193, 171	251, 245, 223, 183, 147	255, 249, 216, 179, 154
Length to origin of tail as free appendage on ventral surface	848	895	859	846
Tail: width at origin on ventral surface, depth here	74, 37	82, 46	78, 36	79, 36
Tail: width at origin on dorsal surface	93	103	84	103
First dorsal: length to origin, base, height	....	....	1189, 80, 53	....
Interdorsal	....	....	18	....
Second dorsal: base, height	....	....	72, 40	....
Clasper: free inner length, outer length	....	78, 48	102, 50	100, 56
Clasper: width at outer attachment, depth there	....	15, 9	16, 8	18, 9
Distance between bases of claspers	....	57	52	51
Outer pelvic lobe: length of external border, of internal border (chords)	123, 57	110, 66	100, 50	113, 71
Inner pelvic lobe: length of external border, of internal border (chords)	141, 95	154, 90	163, 104	174, 80

of the tail was chopped off immediately the entry was handed in at the check-point: however, the severed section of (*b*) was recovered, making possible the measurement of total length in that individual.

Family **CLINIDAE**

Genus **CLINUS** Cuvier [1816]

Clinus perspicillatus Cuvier & Valenciennes, 1836

Clinus perspicillatus Cuvier & Valenciennes, 1836, Hist. Nat. Poiss., xi: 372. Type locality: Westernport, Victoria (Quoy & Gaimard).

Clinus despicillatus Richardson, 1839, *Proc. Zool. Soc. Lond.*: 97. Type locality: Port Arthur, Tasmania.

Dorsal radial pattern.—Published counts of the spines of the first dorsal are invariable at three, and no other number has been observed in any specimen examined by the writer: this is the characteristic number among Australian Clinids, though counts of three and two have been noted for *Petraites johnstoni* (Saville-Kent, 1866).

The traditional ranges for the second dorsal of the present species of xxxii-xxxiv + 3-5, as reported by McCulloch (1908: 43) and still cited in Scott (1962: 253), were extended in the last contribution in this series to xxxi-xxxv + 2-5. While this range stands, and while no new southern material has been obtained to permit further investigation of a formally significant difference in mean number of dorsal radial elements reported in Part XIV (Table VI: 106) as characterizing samples from Taroona, Buckingham, and Green's Beach, Devon, examination of additional examples from the latter locality has made evident an interesting feature of the overall second dorsal pattern, the existence of which can now with hindsight be observed in the frequency distributions of these samples (1966, Table VII: 107), but which is perhaps there not immediately obvious.

Table II exhibits the frequency distribution of 203 northern fish from Green's Beach (comprising (*a*) three pooled sets of 29 specimens specified earlier (1966: 105) and newly examined sets of (*b*) 23, (*c*) 15, (*d*) 96, (*e*) 40 collected by Mr R. H. Green on 5th April, 11th September, 17th October, 19th December, 1965, respectively); together with (*f*) the 11 southern fish from Taroona, collected by Mr C. Scott, previously reported on (1965: 60; 1966: 105). It will be observed: (*i*) the pooled frequency distribution of number of spines, shown in the extreme right-hand column of the table, is tolerably symmetrical and approximates a binomial distribution with initial and terminal curtailment (*cf* $(0.5 + 0.5)^5$ which yields 7, 33, 67, 67, 33, 7); (*ii*) for a given spine number the modal ray count occurs centrally, and the distribution shows some approach towards symmetry (the pooled figures—2 rays, (1 fish), 3 (38), 4 (152), 5 (23)—exhibiting, like the spine totals, some degree of negative asymmetry); (*iii*) the patterns exhibited by the pooled values are more or less evident also in the sectional totals (thus, *e.g.*, for the 96 specimens of the largest sample the distribution of spine number found is (0), 21, 41, 31, 3, 0: the expansion of $(0.5 + 0.5)^5$ gives 3, 15, 30, 30, 15, 3). These results would suggest, first, that spine number and ray number in the second dorsal fin are controlled by separate genetic mechanisms; secondly, that the mechanism is in each case polygenic.

A further indication of the behavioral independence of the two sections of the second dorsal is afforded by the pigmentation, which differs notably in the spinous and rayed regions in respect both of its nature and its time of onset. The history of the large spinous portion is as follows. At standard lengths below about 20 (some variation is found both in individuals and in samples), this region is either (*a*) wholly clear, or (*b*) if not clear, it may be tinged yellow proximally, with or without some distal duskiness, or may exhibit about 6 yellowish areas at subequal intervals (the modal situation in non-clear fins), or, occasionally, may present some early indication of the replacement of the yellow areas by dusky bars. Subsequent development results in the strengthening of these bars, till each comes to involve about 3 spines, and often leads also to their more definite association with 6 dark spots in a line along the dorsal profile of the body, which themselves expand, reinforcing this association. The general gradients of this progressive pigmentation of the fin are from basal to proximal, and from anterior to posterior regions. Still later, pigmentation may be laid down between the bars, most commonly in the form of 2-3 subspherical clusters of melanophores on each spine, and, on the membrane, diffuse clouding, more or less intense and extensive according to the general degree of pigmentation of the individual. The short rayed portion of the dorsal may remain wholly clear of pigmentation in individuals of standard length of 60, and upwards: when pigmentation is present, which is seldom the case in fish of *Ls* less than 50, it first involves the rays, in sequence caudad, after which the punctulation may briefly invade the outer portion of the membrane between the 1st and 2nd rays, and, subsequently, usually to a lesser extent, that between the 2nd and 3rd rays, only exceptionally extending further caudad—at all stages the rayed portion almost invariably standing out as conspicuously lighter overall than the spinous portion.

Frequency distribution of anal rays.—For 136 specimens (29 from Green's Beach, 11 from Taroona, both specified in Part XIV, 96 from Green's Beach collected 18th, 19th December, 1965) the frequency distribution of the anal rays is 21 (1 fish; from Taroona), 22 (5), 23 (36), 24 (64), 25 (29), 26 (1, from Green's Beach); the good approach to symmetry probably being indicative of ray number being under allelic control. As is the case with the dorsal rays noted above (214 specimens), the arithmetic mean is less (though here less markedly so) than the unitary mode.

Secondary sexual dimorphism.—The finding, noticed under Ophiclinidae in this contribution, of the existence in members of that family there discussed of regular differences in overall size and in certain proportions characterizing the sexes has suggested the examination of data for a Clinid for which fairly extensive series are available to ascertain if they occur also in this group. Three samples have been examined, containing 67 (29 males), 17 (8 males), 14 (4 males), all from Green's Beach

TABLE II.

Clinus perspicillatus Cuvier & Valenciennes, 1836. Frequency distribution of spines and rays of second dorsal fin for 203 specimens from Northern Tasmania, 11 from Southern Tasmania (specifications of series (*a*)-(*f*) in text)

Formula S_i R_i	Northern						Southern	Pooled	
	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	Total	(*f*)	$\Sigma S_i R_i$	ΣS_i
xxxi, 2								0	
3	1	1	1	2		5		5	36
4	1	4	5	18	2	30		30	
5				1		1		1	
xxxii, 2								0	
3	2	3	2	10		17		17	82
4	11	4	3	26	11	55		55	
5	2	1		5		8	2	10	
xxxiii, 2	1					1		1	
3	1	3	1	6	2	13		13	77
4	8	5	1	19	14	47	5	52	
5	1			6	4	11		11	
xxxiv, 2								0	
3					3	3		3	18
4	1	2	2	3	4	12	2	14	
5							1	1	
xxxv, 2								0	
3								0	1
4							1	1	
5								0	
Total	29	23	15	96	40	203	11	214	214

(17th October 1965, comprising the larger examples of the series used in Table II; 14th December 1964, portion of series quoted in Tables VI, VII, from Part XIV; part of a collection made on 18th, 19th December 1965, respectively) with the results here noted.

(*i*) *Absolute size.* Standard length ranges and means for the three series, in sequence as above, are: males 37.7-84.9, $\bar{x}$ 64.71 ± 1.57, females 46.8-84.3, $\bar{x}$ 61.59 ± 1.46; males 30.1-51.1, $\bar{x}$ 36.51 ± 2.32, females 24.4-43.8, $\bar{x}$ 33.03 ± 3.40; males 81.1-94.0, $\bar{x}$ 87.60 ± 2.29, females 69.1-86.0, $\bar{x}$ 79.49 ± 2.23. Female *Ls* is thus, in these samples, 95.2%, 86.2%, 91.0% of male *Ls*. It will be seen that, as might be expected with samples of this sort from general collections, the size ratio varies considerably. With variances high, there is in no instance a statistically significant difference in the sex means (t = 1.20, 1.08, 2.0, respectively), but the occurrence in all samples of a male excess is probably indicative of the existence of an actual difference of overall size in the sexes in this species.

(*ii*) *Relative lengths of trunk.*—Ranges and means of trunk length, expressed as *TLs*, for the same samples are: males 123-190, $\bar{x}$ 148.6 ± 2.23, females 138-223, $\bar{x}$ 172.6 ± 3.74; males 130-159, $\bar{x}$ 144.5 ± 1.59 females 127-162, $\bar{x}$ 146.7 ± 3.18; males 146-173, $\bar{x}$ 156.8 ± 5.96, females 140-191, $\bar{x}$ 159.0 ± 5.17. The length, relative to standard length, of the trunk in males is thus, in these samples, 86.1%, 98.6%, 97.5% of that of the females; with the value for the largest sample possibly providing the best estimate of the ratio. With the 3 samples pooled, the difference of the male and female means yields t = 4.42**.

(*iii*) *Relative lengths of vertical fins.*—Measurements needed for the calculation of the dorsal base/anal base ratio were not recorded for this material.

Genus **PETRAITES** Ogilby, 1885

Petraïtes phillipi (Lucas, 1891)

Cristiceps phillipi Lucas, 1891, *Proc. Roy. Soc. Vict.* (n.s.), iii; 11, pl. iii., fig. 2. Type locality: Port Phillip, Victoria.

Petraïtes phillipi (Lucas). McCulloch, 1908, *Rec. Aust. Mus.*, vii, 1: 43, pl. x, fig. 3.

Occurrence.—Three specimens, *Ls* 40.5 (parous female), 47.0 (male), 51.6 (parous female), obtained by Mr R. H. Green at Green's Beach, Devon, and noted in Part XIV (1966: 109) constitute the first record of the species for Tasmania. It is, however, apparently not uncommon here, other examples being present, in association with *Clinus perspicillatus* and other species, in intertidal rock-pool collections made at the same locality by Mr Green as follows: 2 specimens, probably females, *Ls* 34.7, 40.6, on 5th April 1965; 2, *Ls* 64.0 (female distended with young), 64.2 (female) on 11th September 1965; 16, *Ls* 46.0-81.1, $\bar{x}$ 64.2 ± 3.1, σ 12.20 ± 2.16, *V* 19.0 ± 3.5 (8 females, 2 with young) on 18th, 19th December, 1965.

Abnormal specimen.—One fish of the December series, *Ls* 79.9, *Lt* 90.9, presents some unusual features. Both rostral and ocular tentacles are quite exceptional, exhibiting a complexity of ramification equalling, or exceeding, that characteristic of *P. johnstoni* (Saville-Kent, 1866), in which branching is more extensive than in any other common Australian Clinid (see Scott, 1966, fig. 1). The appendage surmounting the narial cylinder, normally a flattened ovate entire lobe, with major axis subequal to height of cylinder, is here a fairly stout rod terminating in 4 slender digitate processes, the longest reaching, with organ laid back, halfway to base of ocular tentacle. That tentacle, characteristically a rather broadly ovate or panduriform lamella, with distal margin entire, or at most but slightly crenulate, here presents a large flattened foursided flap, from the wide posterior border of which arise 6 long, very slender, tapering processes, several of which, when laid back, reach to base of 1st dorsal spine. Exceptional terminal processes (possibly resulting from the same physiological peculiarity as that which has produced excess development in the tentacles) characterize the dorsal spines. The 1st and 3rd spines of the first dorsal each bear a cluster of 4, the 2nd a group of 5, fingerlike appendages, the largest 3.5 long, equalling length of snout. A single filament occurs on each of the spines, though on none of the rays, of the second dorsal, ranging in length from rather less than one-third to more than half the length of the part of the spine (almost the whole extent) that is encased in membrane. Quite apart from its adventitious processes, the first dorsal is notably larger than customary, reaching, on being adpressed, to the base of the 7th, instead of the usual 2nd-4th, spine of second dorsal. On the other hand, the second dorsal and the anal, adpressed posteriorly, fail to achieve (commonly extending well beyond) the level of the hypural joint.

Dorsal radial pattern.—The range for dorsal spines and rays given by McCulloch (1908: 43), which incorporates that of the type material (Lucas, 1891: 11), and which is not transgressed by our earlier material (1966: 109), is iii, xxx-xxxii, 2-3. Three of the present series (one being the unusual individual just considered) have 4 rays. The frequency distribution for the second dorsal, with the 3 examples recorded in Part XIV included, is: xxx, 3 (8 fish), xxxi, 2 (3), xxxi, 3 (7), xxxi, 4 (1), xxxii, 3 (3), xxxii, 4 (1). The distribution (8, 11, 4) of the 3 spine classes and the distribution of rays (3, 7, 1) within the only one of these classes exhibiting more than one ray number follow, with reasonable fidelity for so small a sample, the general pattern already found in *Clinus perspicillatus;* and are probably indicative here also of separate genetic mechanisms for spine number and ray number, both involving alleles.

Petraïtes heptaeolus Ogilby, 1885

Petraïtes heptaeolus Ogilby, 1885, *Proc. Linn. Soc. N.S.W.*, x: 225 [as *nom. nud.* on p. 10]. Type locality: Port Jackson [New South Wales].

Cristiceps wilsoni Lucas, 1891, *Proc. Roy. Soc. Vict.* (n.s.), iii: 10, pl. iii, fig. 1. Type locality: Port Phillip, Victoria.

Corrections.—In Part XIV (1966: 109) the trivial name is misspelt *heptaelus* in the first line of the synonymy; and in the two paragraphs under *Fin counts* xxx regularly appears in the second dorsal spine counts in error for xx.

Remarks.—This species was not reported from Tasmania for eighty years after its establishment, the first record for this State, based on 3 examples from Green's Beach, Devon, being made in Part XIII (1965: 59), 2 further specimens were later noted (1966: 109). Rock-pool collecting by Mr R. H. Green at Green's Beach on 18th, 19th December 1965 has yielded 2 females, (*a*) *Ls* 43.6, *Lt* 54.0, (*b*) *Ls* 52.4, *Lt* 64.0, the smaller containing a number of embryos, a record that reduces the already small size (*Ls* 55.5, *Lt* 65.0) reported for a parous female. Both fish have D. iii, xxvii, 1 + 2; A. ii, 20. Three examples, all from Green's Beach, have been noted in the collections of the Queen Victoria Museum, Launceston—(*c*) male, *Ls* 44.9, *Lt* 54.2, D. iii, xxviii, 1 + 2, A. ii, 21; (*d*) male, *Ls* 49.4, *Lt* 61.0, D. xxviii, 1 + 2, A. ii, 21; (*e*) female, *Ls* 54.9, *Lt* 64.5, D. iii, xxvii, 1 + 2, A. ii, 19. Specimens (*c*), (*d*) (labelled *Clinus perspicillatus*) were collected by Mr R. H. Green on 5th May, 1962, (*e*) is without date.

Intromittent organ.—The intromittent organ, which is pale yellow, without markings, shows a semicircular anterior basal fold, deepest mesially, from which projects a forwardly curved subconical process with, on its anterior surface, near its distal one-third, a large crescentic groove or slit, bounded below by a tumid lip and overhung by the distal portion of the main process, the tip of which is perforated. With minor variations, chiefly of proportions, this description is applicable to *Petraïtes phillipi* and to *Clinus perspicillatus*: the general formation differs considerably from that of the intromittent organ of one South African clinid, *Pavodinus litorafrontis* Penrith, 1965, figured by Penrith (1965, fig. 1), but agrees tolerably well in basic plan with that of *Gynutoclinus rotundifrons* (Barnard, 1937) shown (fig. 4) in the same paper. However, while specimen (*c*) was being examined, a slender tubular extension (not previously observed by the writer in any local species), about one-third as long as the rest of the organ, became extruded through the aperture hitherto terminal; shortly afterwards spontaneously retracting to become invisible. Partial redeployment was brought about by the application of pressure near the base of the penis.

Disposition of dorsal rays.—The general disposition of the dorsal rays as figured by McCulloch (1908, pl. xi, fig. 1)—the 2nd and 3rd rays close together, the 2nd separated from the 1st by an interval considerably exceeding that between 1st ray and last spine—characterizes all Tasmanian examples studied, but in our material the last 2 rays do not always run more or less parallel, as depicted, but commonly are bowed, coming to lie much closer together near the middle of their length than at their approximately equally disparted proximal and distal ends. In some individuals the 1st ray is much closer to the last spine than the latter is to the penultimate spine. The general pattern of the dorsal rays remains, however, highly characteristic, permitting the recognition of the species at a glance.

Disposition of anal rays.—The echoing of the dorsal rays by the posterior rays of the anal, as shown by McCulloch, but noted by him as not being invariable, is in our material a quite unusual arrangement.

Family OPHICLINIDAE

The retention of the family name Ophiclinidae in preference to Stichariidae has been discussed earlier (1965: 61; 1966: 113).

Species known to occur in Tasmania—all the distribution entries postdating the Check-List—are: (*i*) *Ophiclinus greeni* Scott, 1936 (Tasmania only), (*ii*) *Ophiclinus gracilis* Waite, 1906 (also Victoria, New South Wales); (*iii*) *Ophiclinus gabrieli* Waite, 1906 (also Victoria); (*iv*) *Ophiclinops varius* (McCulloch & Waite, 1918). Of these (*i*) was described since the Check-List appeared, (*ii*) was reported by Olsen (1958: 57) from George Bay, Somerset/Cornwall; (*iii*) (*iv*) have been noted in these observations (1965, 1966). To this list may now be added (*v*) *Ophiclinus aethiops* McCulloch & Waite, hitherto known (Scott, 1962: 250) only from the original material taken at Kangaroo Island, South Australia, (*vi*) *Breona greeni gen. et sp. nov.*

A key to Tasmanian and ad-Tasmanian species is supplied, and some observations are made on all locally occurring forms, a good series of *Ophiclinus aethiops* providing material for an extended description of this little-known species, including the question of its status *vis-à-vis O. gabrieli.*

Lateral line.—The lateral line in the best-known genus of the Ophiclinidae, namely, *Ophiclinus sensu lato*, has hitherto been reported either (*a*) as being restricted to a rather short segment, made of contiguous tubules, running longitudinally a little below the dorsal profile, and not extending noticeably beyond level of end of adpressed pectoral (*Ophiclinus, sensu stricto*), or (*b*) as being obsolete (*Ophiclinops*, as that genus is understood in these Observations; see Part XIV, p. 113). In *Ophiclinus greeni* and in fish here determined as *O. aethiops* and *O. gabrieli* a second lateral line segment, in the form of a line of regularly spaced pores, originating behind and below the tubulous segment, and running (either from, or very shortly after, its anterior end) more or less horizontally, near the midlateral line, along the rest of the trunk and most, or all, of the tail has been observed. In *Ophiclinops varius*, stated to be without any lateral line, there has been detected a mediolateral series of pores, taking its origin a little behind the head, and extending to, or almost to, caudal base. In the newly described *Breona greeni*, which is without ordinary scales on the body, there occurs (in addition to a long anterior, superior line of tubules, reaching to, or beyond, level of vent) a median row of spaced scales on the tail. Details are noted under the several species, and the complete lateral line system is schematically depicted for *Ophiclinus aethiops* (Fig. 1) and for *Ophiclinops varius* (Fig. 2). With some indication, as in, *e.g.*, *O. aethiops*, first, of some downturn of the upper segment, and, secondly, of the presence of one or two pores located on the downward and backward line drawn from the last tubule to the first pore of the midlateral series, the overall arrangement in *Ophiclinus, s.s.*, thus approaches the general plan found in the Clinidae: in *Ophiclinops*, however, we seem to be presented with the more common unspecialized single mediolateral pore-line. In the compilation of the subjoined key it has been assumed that the nature of the lateral line found in the species of

Ophiclinus and *Ophiclinops* it has been possible to examine characterizes also the remaining species.

Secondary sexual dimorphism.—It has been found that the relative length of the trunk, and, concomitantly, the magnitude of the ratio dorsal base/anal base are greater in females than in males.

KEY TO TASMANIAN AND AD-TASMANIAN OPHICLINIDAE

The key includes [in square brackets] two species not hitherto reported from Tasmania, *Ophiclinus antarcticus* Castelnau, 1872, *Ophiclinops pardalis* (McCulloch & Waite, 1918). The unsatisfactory state of our present knowledge of the status of *Ophiclinus gabrieli* Waite, 1906 and *O. aethiops* McCulloch & Waite, 1918 is reflected in recourse being had in couplet 6 to quoted specifications.

1 { One lateral line. Pectoral shorter than eye. Dorsal originating behind head by about an eye diameter 2
1 { Two lateral lines. Pectoral longer than eye. Dorsal originating either above head or behind head by about a head length 3

2 { Dorsal spines > 48 (53). Anal rays > 33 (39). Trunk > 2½ (about 2⅞) in length behind vent without caudal fin .... [*Ophiclinops pardalis*]
2 { Dorsal spines < 48 (41-44). Anal rays < 33 (26-29). Trunk < 2½ (about 2) in length behind vent without caudal fin .... *Ophiclinops varius*

3 { Dorsal originating above head. Dorsal base/anal base > 1.2 (1.3-1.7). Tubular anterior segment of lateral line < head 4
3 { Dorsal originating behind head (by about a head length). Dorsal base/anal base < 1.2 (10.-1.1). Tubular anterior segment of lateral line > head .... *Breona greeni*

4 { Total dorsal and anal radial elements > 98 (100-103). Anterior segment of lateral line 'a little longer than eye'; extending about to level of 3rd dorsal spine .... [*Ophiclinus antarcticus*]
4 { Total dorsal and anal radial elements < 98 (75-95). Anterior segment of lateral line at least twice eye; extending beyond level of 3rd dorsal spine (to about 5th—10th) 5

5 { Dorsal originating above opercular border (without lobe). Pectoral < postorbital head. Total dorsal and anal radial elements > 86 (87-95). Not conspicuously bicolor 6
5 { Dorsal originating in advance of opercular border (without lobe). Pectoral ≧ postorbital head. Total dorsal and anal radial elements < 86 (76-85). Conspicuously bicolor 7

6 { 'Vomerine teeth pointed, forming an angular row or series' .... *Ophiclinus gabrieli*
6 { 'Vomerine teeth' [mostly] 'tubercular, forming a triangular' [or other shaped] 'patch' .... *Ophiclinus aethiops*

7 { Dorsal spines < 45 (43). Anterior segment of lateral line strongly arched; markedly bent down posteriorly, its tip about on the horizontal line joining upper border of eye and upper angle of caudal peduncle .... *Ophiclinus gracilis*
7 { Dorsal spines > 45 (46-49). Anterior segment of lateral line nearly straight; not, or scarcely, continued obliquely downwards posteriorly, its tip equidistant from dorsal profile and the horizontal line joining upper border of eye and upper angle of caudal peduncle .... *Ophiclinus greeni*

Genus **OPHICLINUS** Castelnau, 1872

Ophiclinus aethiops McCulloch & Waite, 1918

(Figure 1)

Ophiclinus aethiops McCulloch & Waite, 1918, *Rec. S. Aust. Mus.*, I, 1: 57, fig. 29. Type locality: Kangaroo Island [South Australia].

Ophiclinus aethiops McCulloch & Waite. McCulloch, 1929, *Mem. Aust. Mus.*, V. iii: 352. *Id.* Scott, 1962, Marine and Fresh Water Fishes of S. Aust.: 249, unnumbered fig. on p. 250.

Remarks.—This species, based on a holotype 65 long and a second 'slightly smaller' example, was one of the three new species of *Ophiclinus, sensu lato,* described by McCulloch & Waite in their observations on the genus in 1918. As recently as 1962 Scott stated it had not been collected since.

Tasmanian record.—Ten specimens, *(a)-(j)*, *Ls* 99.0-125.6, $\bar{x}$ 109.77 ± 2.79, σ 8.81 ± 1.97, *V* 8.0 ± 1.8, *Lt* 110-138.2, $\bar{x}$ 121.59 ± 2.99, σ 9.33 ± 2.08, *V* 7.7 ± 1.7, are included in a fine collection of rock-pool fishes obtained with the use of rotenone at Green's Beach, Devon, by Mr R. H. Green on 18th, 19th December 1965. One individual was secured on the 18th, the others, from the same pool, the next day.

Status.—The present material is referred to this species with some hesitation. If it is not *O. aethiops* it is *O. gabrieli* Waite, 1906; its examination raising some question as to the distinctness of these two forms. The key to 6 species of *Ophiclinus, s.l.*, given by McCulloch & Waite (1918: 55) makes a primary division into one group with pectoral longer than eye, lateral line present anteriorly, and another with pectoral shorter than eye, lateral line obsolete [dorsal commencing well behind head]; the second group constituting the genus *Ophiclinops* Whitley, 1932 [as understood by T. D. Scott (1962: 250, 251) and in these Observations (1966: 113)]. A subdivision of *Ophiclinus, s. str.*, sets in contrast a section (containing ? *O. sulcatus* (Castelnau, 1872) and *O. aethiops*) with vomerine teeth 'tubercular, forming a triangular patch', and a section (*O. gabrieli* and *O. gracilis*) with vomerine teeth 'pointed, forming an angular row or series'. In the Green's Beach material the vomerine teeth exhibit characters that, taken independently, could lead to their relegation to either one, or to both, of the categories of the key. They are mostly tubercular, but one or two, or several, may be pointed; they may be disposed chiefly in a patch, with or without some prolongation backward from the angles of the base, or the most prominent feature of the set may be an angular arrangement, with some additional teeth occurring near the apex of the inverted *V*: where this last-described arrangement obtains there is a tendency for at least some of the teeth on the limbs of the inverted *V* to be pointed. The differences are not strictly correlated with sex, though the diffuse tubercular patch is perhaps somewhat more noticeable in females.

Apart from dentition, the features in which *O. gabrieli* and *O. aethiops* are described as differing are (*i*) dorsal formula, (*ii*) anal formula, (*iii*) coloration: these may now be considered. (*i*) Only one dorsal count, li, 1, is reported for *O. gabrieli*

and only one, liv, 1, for *O. aethiops*. Our material embraces both these values, yielding li, 1 (*c*), lii, 1 (*a*), liii, 1 (*g*), liv, 1 (*b*), (*e*), (*f*), (*h*), (*i*), lv, 1 (*j*), lvii, 1 (*d*). (*ii*) *O. gabrieli* stands alone among the species of *Ophiclinus, s. l.*, described this century in having the anal formed wholly of soft rays; all other such species being reported as possessing 2 or (*O. gracilis* Waite, 1906) 3 spines [an original report of 3 spines for *O. greeni* Scott, 1936, has since been altered to 2 (see under that species in the present contribution)]. However, it is to be remarked that from an external examination the initial elements of the anal in the present material might well be taken to be soft rays, the more so as, in several specimens, these and/or more caudal elements present a curious (quite illusory) suggestion of being branched. Dissection of 3 examples reveals 2 non-septate elements, the first small, at the beginning of the anal. (*iii*) As regards color pattern all the females and the smallest male can be taken to be well represented by the illustration of the holotype of *O. gabrieli* (Waite, 1906, pl. xxvi, fig. 7; fig. 6 in legend): the other males tend to be more uniformly dark brown, and would seem visually to qualify quite well for a trivial name of *aethiops*. Unfortunately the only available illustration of *O. aethiops* is the original simple outline figure (washed in evenly in Scott's South Australian handbook). Black dots on the head body and fins reported for the type are noted as lacking in a 'slightly smaller example'; *O. gabrieli* is described as having fins other than anal and caudal without markings: no conspicuous system of black dots is present in the Green's Beach fish. 'Dorsal and anal fins with alternate light and dark bands, the former the narrower' (*O. aethiops*) would scarcely be a natural description of any of our specimens, though some of them exhibit darker and lighter regions; the relative disposition of which is, however, highly variable. Pectorals, ventrals and caudal appear to be in a few individuals all or severally immaculate: other examples exhibit irregular spotting, ranging from rather conspicuous to barely discernible.

With overlapping in dorsal count and with partial conformity in respect of specification of dentition and coloration exhibited by the present material when set against these features as reported for *O. gabrieli* and *O. aethiops*, the sole criterion left would seem to be the composition of the anal; here *O. aethiops* is unequivocally indicated. In view, however, of the uniqueness within *Ophiclinus, s.l.*, of the wholly articulated anal radial complement reported for *O. gabrieli*, the question as to whether *O. aethiops* is a synonym of Waite's species remains open.

If correctly attributed to *Ophiclinus aethiops* McCulloch & Waite, 1918, these specimens provide the first record of this species for Tasmania (and apparently the first report of the fish since the original account).

Possible age groups.—Individual standard lengths are recorded (along with some proportions) in Table III. It will be seen examples (*h*), (*i*), (*j*) are noticeably larger than the rest. With the sample divided into two groups of 7 and 3, *Ls* specifications of (*a*)-(*g*) are range 99.0-106.1, $\bar{x}$ 104.29 ± 0.93, σ 2.45 ± 0.65, *V* 2.1 ± 0.6; and for (*h*)-(*j*) range 115.0-125.6, $\bar{x}$ 122.57 ± 1.58, σ 2.73 ± 1.09, *V* 2.2 ± 0.9. The difference of means is highly significant (t = 9.34**); the values of *V* are suggestive of homogeneous groups: two age populations are quite probably represented.

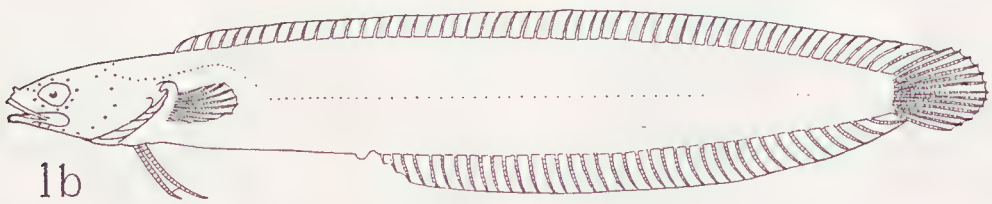
Sex ratio.—There are 6 males, 4 females.

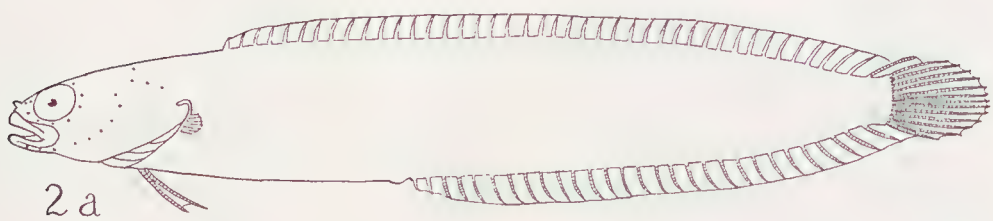
External genitalia.—The penis, which is regularly protruded, is strongly convex posteriorly and laterally, slightly convex, flat, or slightly concave anteriorly; anteroposterior basal diameter 0.5-0.7 transverse basal diameter, the latter subequal to the protruded length, which is subequal to vertical height of anal fin; the crescentic slit invisible from behind, more or less concentric with the whole half ellipse of the periphery of the anterior face, or approaching the margin more nearly at the tip than at the base of the organ, its front lip with a median sulcus, its hind lip entire. Females present an aperture of variable size, the margin more or less complexly lobed, situated at the posterior end of an ovate or pyriform bulbous region, widest anteriorly, with 10-12 longitudinal ridges or plicae running its whole length, which somewhat exceeds distance of opening from origin of anal fin.

Secondary Sexual dimorphism.—(*i*) *Absolute size.*—If two age groups are represented, as *Ls* distribution suggests, females are consistently somewhat smaller than males, the *Ls* of females among specimens (*a*)-(*g*) being 99.0-105.0 $\bar{x}$ 102.17 ± 1.55, compared with the male 105.5-106.1, $\bar{x}$ 105.88 ± 0.11 (for difference of means t = 3.05); and among specimens (*h*)-(*j*) 118.0-124.1, $\bar{x}$ 121.05, against the single entry 124.8. On this assumption of ages, and with these extremely limited data, the mean increase in standard length on proceeding from the first to the second age group would be 15% for females, 18% for males.

(*ii*) *Relative lengths of primary body regions.*—Sexual dimorphism obtains in the relative lengths of two, possibly all, of the primary body regions, head, trunk, tail. Length to vent, as *TLs*, is for females 430-453, $\bar{x}$ 442.0 ± 4.86, for males 398-415, $\bar{x}$ 404.3 ± 2.38: the means are significantly different (t = 6.85**). The additional precaudal length is wholly, or almost wholly, accounted for by the trunk, the difference in head length (females 199-214, $\bar{x}$ 205.0 ± 2.81, males 195-208, $\bar{x}$ 202.6 ± 1.66), while possibly representing a small real variation, not being statistically significant (t = 0.73). For females *TLs* trunk lengths are 225-254, $\bar{x}$ 237.0 ± 5.3, for males 193-214, $\bar{x}$ 201.5 ± 2.1: t for difference of means is 5.72**. Some relative excess in coelomic volume in females of a viviparous fish is perhaps not unexpected. In the present sample, taken as a whole, the relative excess in trunk length in females is sufficiently pronounced to outbalance the deficit (mean 14.9%) in absolute length of female fish; the mean absolute trunk length in females being 25.2, in males 22.7.

(*iii*) *Relative lengths of vertical fins.*—As a concomitant of shorter length behind vent, females have the anal base (extended along almost the whole caudal length) relatively shorter than males, the fin base (measured here between bases of first and last rays, omitting posterior membranous attachment) being, in terms of *TLs*, 509-526, $\bar{x}$ 515.3 ± 3.5 in the former, 539-553, $\bar{x}$ 543.7 ± 2.4 in the





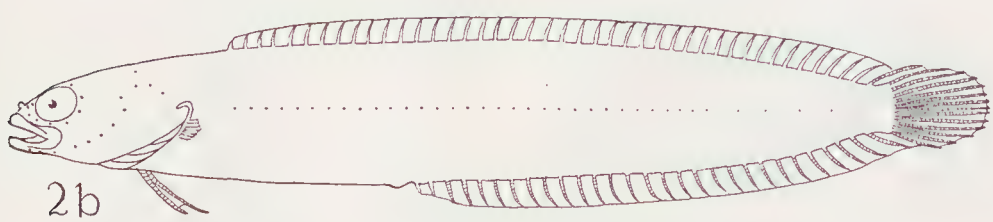


FIG. 1.—*Ophiclinus aethiops* McCulloch & Waite, 1918, to illustrate the lateral line: both figures semidiagrammatic, natural size. *a.*—Fish as conventionally depicted; lateral line consisting only of a short anterosuperior segment of tubules (redrawn from original figure of holotype). *b.*—Showing an additional lateral line segment (mediolateral series of pores), as observed in Tasmanian specimens.

FIG. 2.—*Ophiclinops varius* (McCulloch & Waite, 1918), to illustrate the lateral line: both figures semidiagrammatic, natural size. *a.*—Fish as conventionally depicted; without lateral line (redrawn from original figure of holotype). *b.*—Showing a lateral line (mediolateral series of pores), as observed in Tasmanian specimens.

FIG. 3.—*Breona greeni gen. et sp. nov.* *a.*—Holotype, female: x 2. *b.*—One of a line of spaced scales occurring along mediolateral line (fish otherwise scaleless): x *ca* 125. *c.*—Intromittent organ of a paratype, lateral aspect: x 20.

latter: for difference of means $t = 2.94^*$. On the other hand, the dorsal base, extending on to both precaudal and caudal regions, is found to be relatively longer in females (768-808 $\bar{x}$, 791.5 $\pm$ 14.3; against 769-805, $\bar{x}$ 786.0 $\pm$ 5.4), the difference being, as would be expected (tail length being much greater than—more than twice—trunk length) less than for anal base. The difference in relative lengths of the dorsal in the sexes thus disclosed is slight and is statistically non-significant. However, it quite probably represents a genuine distinction—in this connexion it will be convenient here to make reference to Table III.

Table III serves two purposes, the second being to present a summary of the position in respect to the lengths (as *TLs*) of the vertical fins in 7 Ophiclinids, 3 species being represented only by estimates based on the figures of the holotypes. It will be noticed that, except for dorsal base in *Breona greeni sp. nov.* (an exception discussed below), the following propositions regularly hold good where data for the sexes are available: female dorsal base exceeds male dorsal base; male anal base exceeds female anal base; the ratio dorsal base/anal base is greater in females than in males. Despite the lack, in the case of some individual species, of statistically significant difference between male and female variates, the overall regularity of the pattern disclosed in the table would seem to afford good ground for believing the results recorded are indicative of genuine sexual dimorphism. The one departure from the symmetrical disposition of the maximum means, the displacement, in *Breona greeni sp. nov.*, of that for dorsal length upwards from the female cell in the table to the male cell, actually affords, of course, additional support for the general propositions involved. The close approximation to unity of the ratio dorsal base/anal base in this species—the exhibition of which constitutes the first purpose of Table III—taken in conjunction with the usual male excess over female of anal base, necessarily leads to a relatively greater length in male of dorsal base, which in this species has become virtually equivalent to caudal length and anal base.

(*iii*) *Coloration.*—Females are consistently lighter than males in general ground color. A distinction on the flank between a darker region above, and a lighter region below, the midlateral line, barely developed in most males and conspicuous in none, is more pronounced, both in intensity and in sharpness of demarcation, in all females. All fins tend to be darker in males; the difference characterizing the whole length of the fin in dorsal, anal and caudal, but being more pronounced proximally in pectorals and ventrals.

Fin counts.—D. li, 1 (*c*); lii, 1 (*a*); liii, 1 (*g*); liv, 1 (*b*), (*e*), (*f*), (*h*), (*i*); lv, 1 (*j*); lvii, 1 (*d*). A. ii, 36 in 5 fish; with 35 rays in (*e*), (*g*), 34 in (*a*), (*c*), and 33 in (*b*). Different numbers of rays in the two pectorals occur in (*j*) with left 10, right 11; (*f*) l. 10, r. 12; (*c*), (*h*) l. 12, r. 11: while (*a*), (*b*), (*e*), (*g*) have 12, and (*d*) has 13 rays, in both fins. C. 13 (main rays), except (*e*), 14. Branchiostegals 4.

Comparison of proportions.—Direct comparisons of the 8 proportions recorded by McCulloch & Waite appear below, each entry comprising range, mean, standard deviation, coefficient of variation of our 10 examples, followed in parentheses by the single value of the original description.

Head in standard length 4.7-5.1, 4.91 $\pm$ 0.04, 0.12 $\pm$ 0.03, 2.4 $\pm$ 0.5 (5.5). Depth at origin of anal in head 1.4-1.6, 1.55 $\pm$ 0.02, 0.063 $\pm$ 0.01, 4.1 $\pm$ 0.9 (1.3). Eye in head 5.4-6.1, 5.73 $\pm$ 0.08, 0.25 $\pm$ 0.06, 4.4 $\pm$ 1.0 (4.2). Snout in eye 1.0-1.4, 1.20 $\pm$ 0.03, 0.10 $\pm$ 0.02, 8.2 $\pm$ 1.9 (1.6). Interorbital in eye 1.2-1.5, 1.34 $\pm$ 0.03, 0.10 $\pm$ 0.02, 7.4 $\pm$ 1.7 (2.5). Pectoral in head 2.2-2.7, 2.48 $\pm$ 0.05, 0.15 $\pm$ 0.04, 6.2 $\pm$ 1.4 (2.6). Inner ventral ray in head 1.9-2.4, 2.11 $\pm$ 0.04, 0.13 $\pm$ 0.03, 6.0 $\pm$ 1.4 (1.7). Last dorsal spine in head 3.6-4.4, 4.02 $\pm$ 0.03, 0.093 $\pm$ 0.02, 2.3 $\pm$ 0.5 (3.1). The most striking discrepancy between published and present values, which occurs in the ratio interorbital in eye (our range 1.2-1.5, holotype 2.5), is possibly attributable to different conventions for the measurement of interorbital (unless, indeed, 2.5 is a misprint for 1.5). Snout, taken in our measurements from most advanced point on fish, is perhaps taken by McCulloch & Waite from tip of upper jaw.

Proportions as TLs.—A more extensive series of proportions, calculated as thousandths of standard length, for each of the 10 individuals, is set out in Table IV. The measurement entered as 'depth at caudal peduncle (minimum)' is the depth at the level of the bases of the last ray elements of the vertical fins. Arithmetic mean, standard deviation and coefficient of variation, having been calculated as a matter of routine, are here recorded for ready reference. Over and above their value as formal specifications of the material, the first and second of these are most immediately useful in the direct comparison of other material, of the same or an allied species, with the present series; the chief interest in the third being somewhat more general, residing in the contribution it makes to the question of the magnitude of relative variation to be expected in data of this type—a matter touched upon on various occasions in these Observations (*e.g.* 1953: 143; 1965: 59, 60): for the 34 items in Table IV, *V* ranges from 0.8 to 9.4, with a mean of 4.93, and a mode, with unitary classes, of 6.

As might be expected in a sample covering so small a general size range, no clear correlation between any recorded dimension and *Ls* presents itself; though full head, the (*h*), (*i*), (*j*) entries for which are the lowest, may possibly become relatively shorter in larger fish.

General description.—McCulloch & Waite's account is brief, consisting of little more than a record of the 8 proportions noted above, 5 lines on color markings, and a statement that the species is similar in structure and dentition to *O. sulcatus* (as described by them), from which it is noted as differing, however, in having fewer radial elements in the dorsal and anal. A more extended description of this little-known species is here offered; complementing the fin counts and proportions recorded above.

Head 1.1-1.3, $\bar{x}$ 1.16 (females), 0.9-1.1, $\bar{x}$ 0.99 (males) in trunk, which is 2.2-2.5, $\bar{x}$ 2.36 (females), 2.8-3.1, $\bar{x}$ 2.97 (males) in tail without caudal fin.

TABLE III

Seven Ophiclinids. Dorsal and anal bases, both as thousandths of standard length (*TLs*), and dorsal base/anal base ratio: to illustrate (*a*) the distinctive low value of dorsal base/anal base, approximating unity, in *Breona greeni gen. et sp. nov.*; (*b*) sexual variation in relative lengths of vertical fins in all species considered

Species		Dorsal base, *TLs*		Anal base, *TLs*		Dorsal base/anal base		Material
		Range	Mean	Range	Mean	Range	Mean	
Breona greeni ..	♂	..	621.3	..	605.6	..	1.026	1 specimen
	♀	591–595	593.0 ± 1.4	566–569	567.5 ± 1.1	1.04–1.05	1.045 ± 0.007	2 specimens
Ophiclinops varius	♂	710–717	714.7 ± 1.9	478–503	488.3 ± 6.1	1.43–1.48	1.462 ± 0.012	3 specimens
	♀	712–731	723.2 ± 4.7	451–495	483.7 ± 7.0	1.44–1.62	1.497 ± 0.027	5 specimens
Ophiclinops pardalis		..	*ca* 757	..	*ca* 589	..	*ca* 1.28	Estimated from figure of holotype
Ophiclinus greeni ..	♂	769–809	783.0 ± 5.6	494–524	512.3 ± 3.9	1.46–1.60	1.527 ± 0.018	6 specimens
	♀	768–823	794.7 ± 5.7	485–521	495 ± 3.5	1.51–1.69	1.597 ± 0.022	9 specimens
Ophiclinus gracilis ..		..	*ca* 747	..	*ca* 472	..	*ca* 1.58	Estimated from figure of holotype
Ophiclinus aethiops	♂	769–805	786.0 ± 5.4	539–553	543.7 ± 2.4	1.52–1.70	1.570 ± 0.030	6 specimens
	♀	768–807	791.5 ± 7.2	509–526	515.3 ± 3.5	1.62–1.67	1.647 ± 0.090	4 specimens
Ophiclinus gabrieli ..		..	*ca* 782	..	*ca* 505	..	*ca* 1.55	Estimated from figure of holotype

Elongate, maximum depth 7.1-7.9, $\bar{x}$ 7.37, depth at origin of anal 1.4-1.6, $\bar{x}$ 1.55, in *Ls;* the greatest depth occurring at about the middle of the trunk in 4 specimens, at two-thirds of trunk in 1, at about middle of trunk and vent jointly in 2, at two-thirds of trunk and vent in 1, at vent only in 2. Moderately compressed, maximum thickness 9.5-10.7, $\bar{x}$ 10.20, thickness at vent 10.8-15.4, $\bar{x}$ 12.43, thickness at middle of tail without caudal fin 15.1, 17.7, $\bar{x}$ 16.77, in *Ls*: or these 3 thickness in corresponding depths 1.3-1.5, $\bar{x}$ 1.39; 1.4-1.6, $\bar{x}$ 1.49; 1.8-2.2, $\bar{x}$ 1.96, respectively.

Head as deep as, or, usually, deeper than, wide at opercular border, tapering pretty evenly to tip of snout; in side view upper surface slightly to moderately convex in advance of eye, slightly convex, flat, or first barely convex then shallowly concave behind eye; the dorsum in general but little rounded transversely, the interorbital region nearly flat. Lips fairly large, the lower broader mesially, the upper broader laterally; lower projecting well behind upper. Maxillary evenly rounded, moderately expanded distally; failing to reach level of posterior border of eye by $\frac{1}{10}$ eye diameter (2 specimens), reaching border (3), extending beyond border by $\frac{1}{6}$ (1), $\frac{1}{5}$ (3), $\frac{1}{4}$ (1) of eye diameter. Eye in anterior one-third of head; just failing to cut dorsal profile; its general plane decidedly oblique; slightly exceeding snout (inclusive of lower lip); 1.2-1.5 times interorbital. Interior nostril tubular, tapering distally; its height about twice its basal diameter; inserted just behind upper lip, near horizontal level of lower border of eye; when directed forward, outward and upward, in what is probably its habitual posture, its tip extends to, or just beyond, vertical level of beginning of mouth cleft; internarial equal to direct distance from nostril to orbit. An aperture, somewhat more conspicuous than adjacent openings, lying just outside the orbit at approximately 10 o'clock (left side viewed), directly behind the anterior nostril by a distance subequal to interval between outer bases of anterior nostrils, is probably the posterior nostril; its distance from its fellow subequal to anterior internarial.

Pores on each half of the head include the following: more or less definitely on dorsal surface, (*a*) just internad of anterior nostril; (*b*) about collinear with (*a*) and presumed posterior nostril; (*c*) above orbit, in advance of anterior border of pupil; (*d*) near orbit at about 2 o'clock (left side viewed); (*e*), (*f*), (*g*) approximately collinear with (*d*) and origin of lateral line, (*f*) being closer to (*g*) than to (*e*); (*h*) internad of, and a little back from, (*g*): on lateral surface, (*i*) between anterior nostril and eye, near latter, at about 9 o'clock; (*j*), (*k*) along posterior border of upper half of upper lip; (*l*), (*m*), (*n*), (*o*) in an arc bordering orbit, between (*i*) in front and (*d*) behind; (*p*), (*q*), close together, behind end of maxilla, in general line of gape, by about half length of gape; (*r*), (*s*), (*t*), (*u*), (*v*) continuing back from (*p*) or (*q*) in an arc bordering preoperculum, (*v*) being below and in advance of (*f*), about as far from (*f*) as is (*g*): on ventral surface (*w*), (*x*), (*y*), (*z*) in a line between anterior termination of inner border of lower lip and a point on a level with, and slightly below, end of gape; (*zz*) internad of, and forming an equilateral triangle with, (*w*) and (*x*). On the dorsum there are two median pores, one forming with (*i*) and (*i*) a proconvex arc, one virtually collinear with the (*h*) and (*l*) arc. In some individuals additional smaller pores are detectable. Preopercular margin subcutaneous. Operculum without spines; its membrane attached to upper angle of pectoral base, and reflected to form a bursa; the outer wall with a pronounced subtriangular, pennon-shaped, or somewhat rounded notch, the posterior periphery of which is more or less made good by the inner wall. Gill membranes free from isthmus; joined across it in an evenly proconvex curve very shortly in advance of ventral fin bases.

Teeth in the premaxillaries rather small, subequal, bluntly conical, closely set; in a broad lunule with 4-6 rows anteriorly, the crescent either ending on each side rather bluntly in 1-2 rows at about the middle of the jaw, or extending back briefly as a single series of several teeth. Mandibular teeth in a short patch, 4-6 deep, in anterior one-third, or less, of jaw, being here small, bluntly conical; thence continuing back to end of jaw as a single series, and being decidedly larger, more pointed. Vomerine teeth tubercular, larger than teeth of upper jaw; varying in disposition from a uniserial arc of 8-12 to a crescentic patch 2-3 rows wide mesially. Palatines and tongue edentulous.

Head naked; whole body, including nape, abdomen, pectoral base squamous. Scales loosely embedded, in general not imbricate, the degree of separation showing regional differentiation that is, however, subject to some individual variation; in rather ill-defined subvertical rows, about 50-60 anterior to, about 160-180 behind, vent; at level of vent 40-50 in a vertical row; cycloid; on anterior flank subcircular, 300-400 μ in diameter; on hinder flank oval, about 600μ by 400μ; on front of abdomen elliptical, about 250μ by 200μ.

Anterior lateral line short, originating just above upper angle of preoperculum, the first of its 14-16 pores lying behind cephalic pore (*g*)—see above—by an interval equal to, or somewhat greater than, interval between pores (*g*) and (*f*); ending about below 4th-5th dorsal spine; its course, after a brief initial dip, involving 2 or 3 pores, gently convex upwards, subparallel with dorsal profile, except for the last 1-4 pores, which turn downwards, usually only slightly, but in several individuals quite markedly. As observed above, a second lateral line, hitherto unreported for the genus *Ophiclinus*, occurs in this species (and in others examined). Lying behind and below the first segment, this consists of a line of small simple pores; comprising, first, one or two well-separated pores lying on a line, steeply oblique downward and backward, drawn from the last tubule to almost the midlateral line (a little closer to superior than to inferior profile of fish), secondly, a longitudinal row of pores running from this point caudad, about along the midlateral line, this section containing some 10-12 pores to level of vent, with a further 20 or so to level of middle of anal base, behind which the series, becoming progressively less easy to trace, contains about another score: on trunk and anterior portion of tail pores maintain, with considerable fidelity, a one-to-one correspondence with myomeres. Fig. 1*a* gives a semidiagrammatic representation of the

lateral line as reported for *O. aethiops* by the authors of the species (McCulloch & Waite, 1918, fig. 29); fig. 1 *b* shows the complete system as present in our material.

Dorsal li, 1-lviii, 1 [spine frequency: li (1), lii (1), liii (1), liv (5), lv (1), lvii (1)]. The fin arises very gradually, making precise determination of its point of origin, lying about above posterior opercular border (without lobe), difficult of determination; profile rising rather sharply to about level of end of anterior lateral line; thereafter increasing slowly, evenly to within a dozen, or fewer, spines from end, behind which the lengths of the spines decrease slightly; longest spine 3.1-4.2 $\bar{x}$ 3.71 in head, the single ray as long as, generally longer than, last spine, about half its length lying caudad of end of tail its extreme tip free of the membrane, the latter wholly continuous with caudal membrane; maximum vertical height of fin subequal to eye; fin base (between bases of 1st spine, ray) as *TLs* 7.68-8.07, $\bar{x}$ 788.2, or 3.6-4.1, $\bar{x}$ 3.87, times head [for difference in males and females, see above under *Secondary sexual dimorphism*]. Anal ii, 33-36 [ray frequency: 33 (1), 34 (2), 35 (2), 36 (5)]. The fin originates below 18th-19th dorsal spine; origin behind head by 1.0-1.2, $\bar{x}$ 1.08 (females 1.1-1.2 $\bar{x}$ 1.11; males 1.0-1.1, $\bar{x}$ 1.05) times head, or nearer to tip of snout than to hypural joint by 0.3-0.8, $\bar{x}$ 0.61 (females 0.3-0.5, $\bar{x}$ 0.44; males 0.6-0.8, $\bar{x}$ 0.73) of head; behind the spines, the 2nd (longer) of which is half, or more, first ray, the fin profile tolerably even, the 1st ray being 0.7-0.9, modally 0.8, of the last (anal thus rising much more steeply than dorsal); last ray 3.0-3.9 $\bar{x}$ 3.40 in head, its tip free of membrane, the latter wholly continuous with caudal membrane; vertical height mostly less than, posteriorly subequal to, height of dorsal; base (to base of last ray) as *TLs* 509-551, $\bar{x}$ 532.3 [for sex differences, see above]. Ventral 2. Fin originating very shortly behind free common fold of branchiostegal membranes, about midway between levels of preoperculum and operculum; outer ray 1.1-1.3, $\bar{x}$ 1.23 in inner, the latter 1.9-2.4 $\bar{x}$ 2.11 in head; brought forward, reaching about to level of eye; external border of membrane a short transverse arc, very shortly below tip of outer ray; fin bases almost contiguous. Pectoral 10-13, modally 12. Fin rounded; the whole, or virtually the whole, border scalloped; longest (6th-9th, modally 8th) ray 2.5-3.4, $\bar{x}$ 2.94 in head; complete fin much longer than (2.0-2.6, $\bar{x}$ 2.33) eye, 2.2-2.8, $\bar{x}$ 2.49 in head; upper angle of base (see above) connected by membrane with opercular lobe. Caudal 13-14, modally 13, main rays. Fin bluntly rounded; when expanded nearly as deep as long; tips of middle 8 or so, occasionally all, rays projecting slightly beyond membrane; length exceeding length of pectoral, subequal to postorbital head with opercular flap; dorsal and anal membranes becoming confluent with it in its anterior one-fifth or one-fourth.

Ophiclinus greeni Scott, 1936

Ophiclinus greeni Scott, 1936, *Pap. Proc. Roy. Soc. Tasm.* (1935): 114, fig. 1. Type locality: Lady Lucy Beach, Low Head [Dorset], Northern Tasmania.

Material.—A fine series of 15 examples is included in an extensive collection made at Green's Beach, Devon, by Mr R. H. Green on 18th, 19th December 1965. For the whole sample length specifications are: *Ls*, range 37.1-85.2, $\bar{x}$ 56.92 ± 3.43, σ 13.30 ± 2.43, *V* 23.4 ± 4.5; *Lt*, range 41.0-93.4, $\bar{x}$ 62.19 ± 3.77, σ 14.60 ± 2.67, *V* 23.5 ± 4.5. With length of the largest individual more than twice that of the smallest, the fish are clearly not coeval. A separation into two size groups originally made by the collector for convenience of storage in different sized containers probably segregates age classes, the *Ls* interval between the entries immediately on either side of the point of division being more than twice that between any two successive entries below it (except for that separating first and second individuals). *Ls* specifications for these two subsamples are: 11 specimens, range 37.1-60.8, $\bar{x}$ 49.78 ± 1.83, σ 6.07 ± 1.29, *V* 12.2 ± 2.6, 4 specimens, range 68.9-85.2 $\bar{x}$ 76.55 ± 2.31 σ 4.69 ± 1.66, *V* 6.1 ± 2.2—the first coefficient of variation being rather higher than one normally encountered in a group homogeneous for age and sex. There is evidence (see below) for variation of size in the sexes in this species.

Anal spines.—In the original description (1936: 114), followed in subsequent accounts (*e.g.*, 1939: 155; 1965: 62), 3 anal spines have been recorded: the same count is given by Waite (1906: 207) for his *O. gracilis*, to which our species is closely allied. The usual number of anal spines in the genus is 2; though an anal wholly composed of rays has been reported (Waite, 1906: 208) for one species, *O. gabrieli*—see under that species and under *O. aethiops* in the present contribution. In the holotypes of both *O. greeni* and *O. gracilis*, as figured, the first three anal radial elements are noticeably shorter than the fourth; and this arrangement characterizes some of the later specimens of the former species, while in others it is only the first two elements that are conspicuously shorter than those immediately following them. Dissection of some of the present, and some other, specimens shows the third radial element is articulated, while the first and second remain non-septate. In *O. greeni* the anal spine complement is thus the 2 modal for the genus; and this perhaps may be the case also in *O. gracilis*. The anal formulae of *O. greeni*, as reported prior to 1965, iii, 31-32, and as in 1965, iii, 29-32, are hence probably to be read as ii, 32-33, ii, 30-33, respectively—the known range, on this assumption of spine number, and with the inclusion of the present material, now becoming ii, 28-33; *cf. O. gracilis*, as reported, iii, 29, possibly representing ii, 30. Overlapping in respect of soft ray number in the anal between *O. gracilis* and *O. greeni*, not evident in the types or in the 1939 material of the latter species, is thus now well established. There continues to remain an absolute distinction in number of dorsal spines (*O. gracilis* xliii, both in original description and in figure (Waite, 1924, fig. 380) of a New South Wales specimen; *O. greeni*, all known examples, xlvi-xlix). All the present examples have the almost straight anterior tubular segment of the lateral line regarded (1965: 63) as characteristic of *O. greeni* (see further remarks on lateral line below).

Fin counts, proportions as TLs.—Dorsal, anal and pectoral fin counts and some proportions, recorded as *TLs*, are set out in Table V.

TABLE IV

Ophiclinus aethiops McCulloch & Waite, 1918. Dimensions, expressed as thousandths of standard length (*TLs*), of 6 males and 4 females from Green's Beach, Devon, Tasmania, collected by Mr R. H. Green, 18th, 19th December 1965

Dimension	Species (Sex; length, mm)										Mean	Standard deviation	Coefficient of variation
	(*a*) ♀ 99.0	(*b*) ♀ 102.5	(*c*) ♀ 105.0	(*d*) ♂ 105.5	(*e*) ♂ 105.9	(*f*) ♂ 106.0	(*g*) ♂ 106.1	(*h*) ♀ 118.0	(*i*) ♂ 124.1	(*j*) ♂ 125.6			
Total length	1,112	1,113	1,105	1,101	1,119	1,103	1,121	1,102	1,104	1,100	1108.0 ± 2.3	7.28 ± 1.63	8.6 ± 1.5
Length to dorsal origin	172	185	172	175	170	193	193	174	186	175	179.5 ± 2.7	8.43 ± 1.88	4.7 ± 1.1
Length to dorsal termination (ray)	969	953	966	966	964	962	962	981	974	980	967.7 ± 2.6	8.20 ± 1.83	0.8 ± 0.2
Length to dorsal termination (membrane)	1,021	1,010	1,023	1,015	1,024	1,019	1,027	1,038	1,010	1,028	1022.6 ± 2.6	8.16 ± 1.83	0.8 ± 0.2
Length to anal origin	447	460	444	417	425	428	434	467	438	422	438.2 ± 4.9	15.57 ± 3.48	3.6 ± 0.8
Length to anal termination (ray)	964	969	953	968	966	967	973	993	979	975	970.7 ± 3.2	9.97 ± 2.23	1.0 ± 0.2
Length to anal termination (membrane)	1,020	1,030	1,015	1,024	1,027	1,013	1,036	1,035	1,024	1,023	1024.7 ± 2.3	7.25 ± 1.70	0.7 ± 0.2
Length to pectoral origin	177	176	174	174	179	174	179	174	181	170	175.8 ± 1.0	3.09 ± 0.69	1.8 ± 0.4
Length to ventral origin	148	146	142	147	142	147	144	148	147	143	145.4 ± 0.4	1.16 ± 0.26	0.8 ± 0.2
Length to vent (middle)	435	450	430	399	401	407	406	453	415	398	419.4 ± 6.3	19.97 ± 4.46	4.8 ± 1.1
Length of longest dorsal spine	57	51	53	56	51	54	63	64	47	60	55.6 ± 1.7	5.22 ± 1.17	9.4 ± 2.1
Length of last dorsal spine	53	49	50	53	47	47	53	47	56	55	51.0 ± 1.0	3.26 ± 0.73	6.4 ± 1.4
Length of dorsal ray	62	60	62	60	66	61	58	48	61	56	59.4 ± 1.3	4.49 ± 0.94	7.6 ± 1.7
Length of longest anal ray	66	75	74	64	58	66	70	67	65	68	67.3 ± 1.5	4.67 ± 1.04	6.9 ± 1.6
Length of first anal ray	56	47	56	56	47	52	48	47	48	49	50.6 ± 1.2	3.80 ± 0.85	7.6 ± 1.7
Length of last anal ray	61	68	66	68	66	65	67	55	60	56	63.2 ± 1.5	4.62 ± 0.99	7.3 ± 1.6
Length of pectoral (whole fin)	91	79	86	85	85	75	89	75	81	80	82.6 ± 1.7	5.21 ± 1.17	6.3 ± 1.4
Length of longest (*nth*) pectoral ray	80(8th)	64(8th)	68(6th)	70(8th)	75(8th)	66(6th, 7th)	75(7th, 8th)	60(9th)	69(7th)	73(7th, 8th)	70.0 ± 1.8	5.62 ± 1.26	8.0 ± 1.8
Length of inner ventral ray	107	98	96	85	100	96	97	102	93	95	96.9 ± 1.7	5.49 ± 1.22	5.7 ± 1.3
Length of outer ventral ray	90	80	74	75	81	74	86	81	72	76	78.9 ± 1.5	4.72 ± 1.06	6.0 ± 1.3
Head, with opercular lobe	202	214	205	204	208	204	205	199	201	195	203.7 ± 1.5	4.86 ± 1.09	2.4 ± 0.5
Head, without opercular lobe	185	185	184	189	187	170	184	187	181	184	183.6 ± 1.6	4.98 ± 1.11	2.7 ± 0.6
Snout	28	29	33	30	26	28	31	28	27	29	28.9 ± 0.6	1.92 ± 0.43	6.6 ± 1.5
Eye	35	39	37	33	37	37	35	34	36	32	35.5 ± 0.6	2.61 ± 0.45	5.7 ± 1.3
Interorbital	28	27	29	28	26	26	28	25	24	23	26.4 ± 0.6	1.85 ± 0.41	7.0 ± 1.6
Depth, maximum	126	132	138	136	140	137	139	136	137	135	135.6 ± 1.2	3.83 ± 0.86	2.8 ± 0.6
Depth at opercular border	114	124	133	131	123	122	123	127	125	127	124.9 ± 1.6	4.97 ± 1.11	4.0 ± 0.9
Depth at vent	126	132	133	124	140	132	131	130	137	135	132.0 ± 1.4	4.48 ± 1.00	3.4 ± 0.8
Depth at middle of tail without caudal fin	117	117	116	113	118	122	119	111	121	113	116.7 ± 1.1	3.38 ± 0.76	2.9 ± 0.6
Depth at 'caudal peduncle' (minimum)	47	49	48	47	47	55	52	45	45	47	48.2 ± 0.9	2.96 ± 0.66	6.1 ± 1.4
Thickness, maximum	91	94	105	96	100	97	94	103	104	99	98.3 ± 1.4	4.47 ± 1.00	4.6 ± 1.0
Thickness behind pectoral base	81	78	86	84	82	68	84	87	88	81	81.9 ± 2.2	7.06 ± 1.58	8.6 ± 1.9
Thickness at vent	81	86	91	85	93	87	84	85	98	95	88.5 ± 1.6	5.16 ± 1.15	5.6 ± 1.3
Thickness at middle of tail without caudal fin	52	58	57	64	58	57	57	58	66	61	58.8 ± 1.2	3.76 ± 0.84	6.4 ± 1.4

TABLE V

Ophiclinus greeni Scott, 1936. Meristic data, and dimensions, expressed as thousandths of standard length (*TLs*), of 6 males and 9 females from Green's Beach, Devon, Tasmania, collected by Mr R. H. Green, 18th, 19th December 1965

Count or Dimension	Specimen (Sex; standard length, mm)															Mode (count) or Mean (dimension)	Standard deviation	Coefficient of variation
	(*a*) ♀ 37.1	(*b*) ♂ 45.1	(*c*) ♂ 47.0	(*d*) ♀ 47.1	(*e*) ♀ 48.5	(*f*) ♀ 49.1	(*g*) ♀ 50.2	(*h*) ♂ 51.2	(*i*) ♂ 53.7	(*j*) ♀ 57.0	(*k*) ♂ 60.8	(*l*) ♀ 68.9	(*m*) ♀ 74.1	(*n*) ♀ 77.8	(*o*) ♂ 85.2			
Dorsal	xlvi, 1	xlvi, 1	xlvii, 1	xlvi, 1	xlvi, 1	xlvii, 1	xlvii, 1	xlviii, 1	xlvii, 1	xlvii, 1	xlvi, 1	xlvii, 1	xlviii, 1	xlvi, 1	xlviii, 1	xlvi, xlvii, 1	..	..
Anal	ii, 30	ii, 29	ii, 29	ii, 28	ii, 29	ii, 28	ii, 29	ii, 29	ii, 30	ii, 28	ii, 30	ii, 28	ii, 30	ii, 29	ii, 31	ii, 29	..	..
Pectoral (left/right)	10/12	13/13	10/13	12/12	12/12	12/12	12/13	13/12	13/13	12/11	12/11	12/11	12/12	12/12	12/12	12/12	..	..
Total length	1,105	1,091	1,085	1,089	1,093	1,103	1,082	1,096	1,086	1,099	1,085	1,103	1,101	1,091	1,096	1093.7 ± 2.8	10.88 ± 1.99	1.0 ± 0.2
Length to—																		
Dorsal origin	189	180	174	170	184	161	180	176	177	174	180	160	158	163	154	172.0 ± 2.6	10.15 ± 1.85	5.9 ± 1.1
Dorsal termination (ray)	957	969	947	965	969	958	957	962	950	965	949	983	978	958	963	962.0 ± 2.5	9.78 ± 1.79	1.0 ± 0.2
Anal origin	480	472	457	474	485	468	473	450	449	474	463	485	464	494	460	469.9 ± 3.2	12.57 ± 2.29	2.7 ± 0.5
Anal termination (ray)	968	967	970	963	969	974	964	965	973	977	970	973	985	978	979	971.7 ± 1.5	5.97 ± 1.09	0.6 ± 0.1
Vent	466	443	447	453	474	454	443	441	436	463	447	466	449	478	433	455.5 ± 3.9	15.12 ± 2.76	3.3 ± 0.6
Length of—																		
Head	235	224	223	232	235	229	219	217	222	226	231	218	205	220	202	222.5 ± 3.0	11.44 ± 2.09	5.1 ± 0.9
Trunk	225	220	223	221	239	225	223	224	214	237	216	248	244	258	231	229.9 ± 3.2	12.22 ± 2.23	5.3 ± 1.0
Dorsal base	768	789	772	795	786	797	777	786	773	791	769	823	821	794	809	790.0 ± 4.3	16.82 ± 3.07	2.1 ± 0.4
Anal base	488	494	513	489	485	505	492	515	524	504	509	488	521	485	519	502.1 ± 3.5	13.64 ± 2.49	2.7 ± 0.5
Eye	40	42	43	43	40	40	39	37	36	37	35	33	32	35	32	37.6 ± 0.9	3.63 ± 0.66	9.7 ± 1.8
Snout	54	52	53	51	45	51	45	51	48	49	49	46	49	50	47	49.3 ± 0.7	2.67 ± 0.49	5.4 ± 1.0
Interorbital	27	28	23	21	22	24	21	21	28	32	29	35	28	30	29	26.5 ± 4.2	4.19 ± 0.77	15.8 ± 2.9
Depth—																		
Maximum	137	135	147	134	134	144	140	139	149	149	146	160	162	177	153	147.1 ± 3.0	11.67 ± 2.1	7.9 ± 1.5
Before anal origin	135	133	130	130	129	132	132	137	138	137	140	135	135	143	151	135.8 ± 1.4	5.35 ± 0.98	3.9 ± 0.7
At hypural joint	54	45	47	43	42	41	46	41	41	40	41	44	40	40	48	43.5 ± 1.0	3.79 ± 0.69	8.7 ± 1.6

Body ratios.—Ranges and means of some diagnostic body ratios of the present material are here given, with previously recorded ranges in parentheses. Maximum depth 5.6-7.5, $\bar{x}$ 6.86 ± 0.13 (6.4-8.1); depth immediately behind vent 6.6-7.8, $\bar{x}$ 7.38 ± 0.07 (6.9-8.4); head 4.3-5.0, $\bar{x}$ 4.50 ± 0.05 (4.3-5.8): in *Ls.* Eye 5.3-6.7, $\bar{x}$ 5.97 ± 0.11 (5.3-7.2) in head; 1.1-1.5, $\bar{x}$ 1.32 ± 0.03 (1.2-1.5) in snout; 0.9-2.0, $\bar{x}$ 1.49 ± 0.08 (1.1-1.2) times interorbital. Head and trunk 1.1-1.3 $\bar{x}$ 1.21 ± 0.02 (1.1-1.4) in tail without caudal fin. Pectoral 1.5-2.2, $\bar{x}$ 1.79 ± 0.04 (1.7-2.1); ventral 1.5-2.1, $\bar{x}$ 1.83 ± 0.04 (1.4-1.9): in head. Caudal 2.0-2.7, $\bar{x}$ 2.41 ± 0.05 (1.9-3.0) in head; 9.5-12.3, $\bar{x}$ 10.70 ± 0.22 (8.8-13.8) in *Ls.* It will be seen that in 5 ratios (maximum depth, depth behind vent, eye in snout, eye times interorbital, pectoral in head) the known range is now extended numerically downward, while in 3 ratios (eye times interorbital, pectoral in head, ventral in head) it is extended numerically upward.

Examination of these ratios—all conventionally employed in specific diagnoses—brings to light some interesting features in some of them. Three ratios, all involving as one term the eye, and as the other terms the snout, the interorbital and the head as a whole, are found to be functions of length of fish. The correlation with *Ls* of the ratio eye in snout is $r = +0.759$, $z = 0.994$, $t = 4.20^{**}$; of eye times interorbital $r = -0.756$, $z = 0.987$, $t = 4.26^{**}$; of eye in head $r = +0.735$, $z = 0.940$, $t = 4.20^{**}$. Moreover, not only are these correlation coefficients large (emphasizing once again the importance attachable to absolute size of type specimens), but the data from which they are derived present the practising systematist with a pretty reliable pattern for estimation of the status of a given specimen selected at random—with 15 pairs of observations there are for the 3 ratios in the order cited above only 1, 2, 0 instances of *dXdy* values of the sign opposite to that of the correlation coefficient; indicative of a quite surprising degree of uniformity.

Sex ratio—There are 6 males, 9 females.

Secondary sexual dimorphism.—(*i*) *Absolute size.* The existence of differences of absolute size in the sexes found in *O. aethiops*, above, has prompted an investigation of male and female lengths in the present species. In the whole sample, females ($\bar{x}$ 56.63 ± 4.35) are slightly smaller than males ($\bar{x}$ 57.17 ± 5.52). The mean lengths are, however, much influenced by the presence of 3 females in the presumed older group of 4 fish; a better indication of relative size is probably obtained by considering the two groups separately: we then find, for 11 fish, female mean 48.15 ± 2.34, male mean 51.6 ± 2.47; for 4 fish, female mean 73.60 ± 1.49, single male 85.2—the excess of male on female in these two groups being 7%, 17%, respectively.

(*ii*) *Relative lengths of trunk.*—As in *O. aethiops* and *O. varius*, length of trunk, relative to *Ls*, is greater in females (221-258, $\bar{x}$ 235.6 ± 2.50) than in males (214-231, $\bar{x}$ 221.7 ± 2.23): the means differ significantly ($t = 4.16^{**}$).

(*iii*) *Relative lengths of vertical fins.*—Differences in relative lengths of trunk and tail entail differences in relative lengths of vertical fins, the anal base being shorter, the dorsal base longer, and hence the ratio dorsal base/anal base higher in females than in males. The differences in anal bases and in the dorsal base/anal base are statistically significant ($t = 2.81^{*}$, 3.15^{*}); but for difference in dorsal base $t = 1.30$. Data on relative lengths of the vertical fins are recorded in Table III. Differences in body form in the sexes in this family such as those here found make apparent the need, not always met, for the sexing of type, or other, material for which metrical data are presented.

Parous females.—All 3 females of the 4 individuals constituting the presumed older group carry eyed ova, the presence of which is rendered evident both by the general distention of the abdomen (more pronounced laterally than vertically: in the present material not nearly as marked as that observed in some Clinids, though this may well be merely a question of the state of development of the embryos) and by indications, rather indistinct, of the presence of eyes observable through the body-wall (much more conspicuous on external examination is the yellow mass of the large sharply pointed somewhat tongue-shaped liver, extending from about the level of the ventral base more than halfway towards the vent). In the largest female, *Ls* 77.8, each fusiform ovarian mass measures 16 long by 5.5 wide by 7 deep. As preserved, both the enveloping membrane and the embryos (apart from the black eyes) are whitish, as also is most of the stroma, the remainder being yellowish. The right ovary contains 117 ova, ranging from 80 by 65μ to 250 by 200μ, the modal dimensions being round about 200 by 160μ. Embryos, still in the egg membrane, have developed to a stage at which the tip of the wrapped-round tail just reaches beyond the beginning of its broad base on the adjacent side. The diameter of the white lens is about 0.2 of that of the whole eye, which is 0.3-0.4 length of head: the choroid fissure is still open, though in some instances barely so. In some individuals pigmentation has begun; in these 17-24 small rounded clusters of melanophores in a median dorsal series are probably segmental. Scattered among the embryos are a few unfertilized ova 75-100μ in diameter, and a small amount of fine fibrous tissue.

Lateral line.—As mentioned above, in a general note on its nature in the best known members of the Ophiclinidae, the lateral line is now found to be composed of two parts.

The conspicuous anterior portion is adequately described and figured in the original account of the species: its general horizontal sense, without posterior downcurve, one of the few points of distinction between *O. greeni* and *O. gracilis*, is there discussed, and has since been commented on in these Observations (*e.g.*, 1965: 63). Its 12-17 perforate tubercles, contiguous or barely separate, extend over a distance somewhat less than a head length.

The newly observed segment consists of a line of small circular pores, of which 5-7 run more or less horizontally along the trunk, the first, which carries the line a little upward, lying shortly behind the level of the last tubule of the upper segment; while on the tail the same line, continued about midway between superior and inferior

profiles, is traceable for at least half the distance from level of vent to hypural joint, with approximately 20 pores.

Ophiclinus gabrieli Waite, 1906

Ophiclinus gabrieli Waite, 1906, *Rec. Aust. Mus.*, vi, 3: 208, pl. xxxvi, fig. 7 (in legend of plate appears as fig. 6). Type locality: Victoria.

Status of Tasmanian record.—In an earlier contribution (1965: 62) two small Ophiclinids, (*a*) *Ls* 45.5, *Lt* 51.2, (*b*) *Ls* 54.1 *Lt* 61.1 (Queen Victoria Museum Reg. No. 1964: 5: 6) obtained at Green's Beach, Devon, by Mr R. H. Green on 13th September 1964 were referred to this species, this being the first notice of it from Tasmania. In the light of the problem as to the relationship of *O. gabrieli* and *O. aethiops* discussed above in observations on the latter species, these two specimens have been re-examined with the results noted below.

(*i*) *Anal formula.*—As the outcome of dissection it has been found that the articulated rays are preceded by 2 unarticulated elements, or spines; these are little, if at all, less flexible than the soft rays succeeding them. Hence, if the specification in the account of the holotype of *O. gabrieli*, 'anal is formed wholly of soft rays' is correct, the present specimens cannot be referred to this species. On the other hand, in respect of their total number of anal radial elements, reported as 36, 35, or as now counted ii, 34 ii, 33, they agree with *O. gabrieli* (holotype 36), and not with *O. aethiops* as described (ii, 36), though in material referred earlier in this contribution to the latter species anal counts range from ii, 36 downwards to ii, 33, thus rendering possible the identification, on the basis of anal formula, with this material of the 2 fish reported as *O. gabrieli*. Points to be considered in evaluating the original report of the absence of anal spines in *O. gabrieli* include (*a*) the presence in all other adequately known species of *Ophiclinus, s.l.*, of 2 (?3) anal spines (in most groups of fishes anal spine number is constant at generic, or higher, level); (*b*) the absence of any emendation by Waite when, in association with McCulloch, he returned to the group in 1918; (*c*) the general superficial resemblance of the 2 spines to soft rays, particularly in regard to flexibility—the weight attachable to these items remains largely a matter of personal judgement.

(*ii*) *Dorsal formula.*—The only formula given by Waite for *O. gabrieli* was li + 1, with which the counts of the 1964 fish, both liii, 1 were considered compatible: but while they fall below the single value for the types of *O. aethiops*, liv, 1, they lie within the range, li, 1—lvii, 1, here reported for the 10 specimens referred to that species.

(*iii*) *Dentition.*—While the original description of *O. gabrieli* merely noted the presence of teeth on the vomer, the species (along with *O. gracilis*) is made to enter, in McCulloch & Waite's 1918 key a section 'Vomerine teeth pointed, forming an angular row or series', the correlate of a section 'Vomerine teeth tubercular, forming a triangular patch', comprising ? *O. sulcatus* (Castelnau, 1875) and *O. aethiops*. The vomerine teeth of our 2 fish are mostly pointed, and are disposed in a lunule or wide somewhat blunted inverted *V*.

(*iv*) *Coloration.*—The coloration is not positively incompatible with either *O. gabrieli* or *O. aethiops*. In lacking the alternate light and dark vertical bands on the anal and dorsal described for *O. aethiops* (but not noticeably developed in the Tasmanian specimens ascribed to that species) the present 2 specimens formally approach *O. gabrieli;* and they certainly exhibit, as described for this species, a decidedly greater degree of uniformity of coloration in the dorsal than in the anal. However, it is difficult to point to any significant difference in coloration between these 2 fish and the smaller females among the 10 fish here identified as *O. aethiops*.

Chiefly on the positive evidence afforded by the general character of the dentition, the earlier ascription (1965: 62) of these 2 specimens to *O. gabrieli* Waite, 1906 may perhaps be allowed to stand. However, pending satisfactory clarification of the relationship of *O. gabrieli* and *O. aethiops*, their definite status remains in doubt.

Lateral line.—In a general note on the family mention has been made of the discovery in *O. aethiops* and some other species of an element of the lateral line hitherto undescribed. In these specimens, from slightly above, and slightly in advance of, the point at which the upper margin of the sleeve-like opercular membrane becomes attached there runs backwards and slightly upwards (in its course either rising continuously to, or flattening out shortly before, its termination) a raised line of 13-17 contiguous perforate tubules; its total length about half head length. This is the lateral line shown in the illustration of the holotype of *O. gabrieli* (though in Waite's figure the general direction more nearly approaches the horizontal than it does in our examples), and is, in essence, that conventionally depicted for the genus *Ophiclinus, s. str.*

The portion of the lateral line now first reported here consists, on the trunk, of a series of 11-12 apertures running more or less horizontally, somewhat nearer to the dorsal than to the ventral profile, the anterior pore being slightly caudad of the last tubercle of the upper segment; with, beyond the vent, a continuation caudad, along about the middle of the tail, almost to caudal base, the total number of pores in this section being difficult of determination but approximating 40. One small pore has been detected near the middle of the downwardly and backwardly oblique line joining the last tubule of the short upper segment and the first pore of the long lower segment.

Cephalic neuromast system.—The locations of the main pores regularly found on the head of *O. greeni* have been specified in observations above on that species. Pores of this kind are a generic feature (though no detailed investigation has so far been made of their exact disposition in the various species). They are commonly apparent simply as discrete subcircular apertures, with no obvious external indication of any connexion with one another. In the present specimens, however, they occur along from tolerably well developed to very clearly defined ridges, arranged on each side of the head in a continuous system, the posterior branch of which comes into direct relation with the

anterior end of the upper segment of the lateral line. The ridges and their pores thus apparently represent a cephalic neuromast system. The actual arrangement is as follows. Anteriorly the lateral line on each side continues forward as a short spur of 2-4 perforations, reaching to the level of the hind border of the preoperculum. From just behind the front perforation a ridge, carrying in all 2 lateral pores and 1 median pore, passes across the dorsum to join the spur from the lateral line of the other side. From the anterior pore of the spur the ridge continues, very briefly, obliquely forward and downward to another pore (from just above which a branch ridge, with 1 pore in its anterior half, runs forward to become continuous with a pore-bearing ridge clearly encircling at least the lower two-thirds of the orbit, and extending, in a less distinct form, round most of the rest of the orbit), from which it swings down in an arc very slightly in advance of, and concentric with, the margin of the operculum, and including 5-6 pores. This cephalic system of ridges is perhaps not so conspicuously elevated in life.

Genus **OPHICLINOPS** Whitley, 1932

Ophiclinops varius (McCulloch & Waite, 1918) (Figure 2)

Ophiclinus varius McCulloch & Waite, 1918, *Rec. S. Aust. Mus.*, I. 1: 57, fig. 30. Type locality: Kangaroo Island [South Australia].

Ophiclinops varius (McCulloch & Waite). Scott, 1962, The Marine and Fresh Water Fishes of South Aust.: 250.

Status of genus.—The scope of *Ophiclinops* as accepted in these Observations has been discussed earlier (1966: 113).

Correction.—In an account (1966: 113) of the first specimen of this species reported from Tasmania there appeared the following passage 'Scott (1962: 250)—who, unaccountably, notes "length 3½ in." . . .' the reference being to T. D. Scott's work on South Australian fishes. However, the really unaccountable circumstance was the careless picking up by the present writer of the size mentioned from the account on the same page of another species: for *O. varius* Scott gives a reasonable '2 in.'.

Material.—Since the collection of the first Tasmanian individual, a female, *Ls* 37.8, *Lt* 42.0, 7 other examples have been taken by Mr. R. H. Green in rock pools at Green's Beach, Devon. In ascending order of *Ls* the 8 are: (*a*) 26.1, female; (*b*) 27.6, male; (*c*) 31.1, female; (*d*) 31.2, male; (*e*) 37.8, female; (*f*) 38.2, male; (*g*) 38.3, female; (*h*) 40.1, female. Specimen (*a*) was collected on 11th September 1965; (*b*), (*c*), (*d*), (*f*), (*h*) on 18th, 19th December 1965; (*e*)—the example reported earlier—on 27th September 1964; (*g*) on 4th-5th September 1965. As would seem likely for the pooled sample with subsamples collected at different dates, the *Ls* coefficient of variation is high, being 15.1 ± 3.8.

Fin counts.—For the dorsal the authors of the species gave xli-xliv, 1 (4 specimens); and all our counts fall within this range (individual counts for dorsal, and other, fins in Table VI): original anal range, ii, 26-28, now becomes ii, 26-29. McCulloch & Waite's entry for pectoral was 8: here, with fins on both sides counted, we have 8 (9 cases), 9 (4), 10 (2)—left fin of (*d*) missing.

Proportions as TLs.—The opportunity is here taken to provide for the first time a tolerably detailed metrical specification of a series of specimens, 34 dimensions expressed as *TLs* being recorded in Table VI.

Body ratios.—For the ratios recorded for the holotype, 45.2 long, the present values are as follows (McCulloch & Waite's figures in parentheses). Head 4.4-5.2, $\bar{x}$ 4.76 ± 0.081 (5.1) in *Ls*. Depth at origin of anal 6.9-7.9, $\bar{x}$ 7.66 ± 0.071 (6.8) in *Ls*. Eye 3.8-4.6, $\bar{x}$ 4.21 ± 0.85 (4.0) in head. Snout 1.4-1.8, $\bar{x}$ 1.61 ± 0.046 (1.6) in eye. Snout 0.7-1.0, $\bar{x}$ 0.77 ± 0.044 in (greater than) interorbital, which is 1.6-2.6, $\bar{x}$ 2.15 ± 0.12 (2.6) in eye. Pectoral 1.1-1.4, $\bar{x}$ 1.25 ± 0.038 (1.3) in eye. Inner ventral ray 1.9-2.4, $\bar{x}$ 2.07 ± 0.10 (2.0) in head. Last dorsal spine 3.6-4.9, $\bar{x}$ 4.26 ± 0.17 (4.0) in head. It will be seen the range is in no instance very narrow, and in some cases is so wide as to make the ratio of little diagnostic significance. For the 9 ratios in the order in which they appear above the coefficients of variation are 4.8, 4.0, 5.7, 8.1, 16.4, 15.2, 8.7, 14.3, 11.1—broadly speaking, $V \leq 10$ should be expectable, with lower values looked for in the case of the major and more basic elements of body form.

Sex ratio.—There are in the pooled material 3 males, 5 females: of the 5 specimens taken at the same time 3 are males.

Secondary sexual dimorphism.—(*i*) *Absolute size.* The mean standard length for females (34.68 ± 2.44) exceeds that for males (32.33 ± 2.54), and within the single sample the excess is maintained. In other Ophiclinids here dealt with females are regularly shorter: differences of means here are nonsignificant, and may well simply represent sampling fluctuations.

(*ii*) *Relative lengths of trunk.*—As in other species examined, the trunk is relatively longer in females (*TLs*, 266.6 ± 6.3) than in males (255.0 ± 6.6): $t = 1.05$.

(*iii*) *Relative lengths of vertical fins.*—The pattern for the sexes encountered in other species holds good for the present form, females having relatively shorter anal base, relatively longer dorsal base, with consequent higher value for the ratio dorsal base/anal base. Statistics are exhibited in Table III.

Lateral line.—The tubular anterior lateral line found in *Ophiclinus s. str.* is lacking in this genus, and the two known species, the present form and *Ophiclinops pardalis* (McCulloch & Waite, 1918), have been described as being without a lateral line of any kind. Examination of our material discloses the presence of a line of simple pores, regularly spaced (on trunk and on at least the anterior two thirds of the tail there is one on each myomere), beginning just behind the posterosuperior region of the opercular border, a trifle nearer to dorsal than to ventral profile of fish, and running back in a virtually rectilinear series to, or near to, caudal base. Anterior to the level of the vent there are about 16 pores; behind this 20 can be counted with certainty, and there may well be a further half dozen. See fig. 2.

TABLE VI

Ophiclinops varius (McCulloch & Waite, 1918). Meristic data, and dimensions, expressed in thousandths of standard length (*TLs*), of 3 males and 5 females from Green's Beach, Devon, Tasmania, collected by Mr R. H. Green

Count or Dimension	Specimen (Sex; standard length, mm)							
	(*a*) ♀ 26.1	(*b*) ♂ 27.6	(*c*) ♀ 31.1	(*d*) ♂ 31.2	(*e*) ♀ 37.8	(*f*) ♂ 38.2	(*g*) ♀ 38.3	(*h*) ♀ 40.1
Dorsal	xlii, 1	xli, 1	xli, 1	xli, 1	xliii, 1	xliv, 1	xliii, 1	xliii, 1
Anal	ii, 28	ii, 27	ii, 27	ii, 29	ii, 28	ii, 28	ii, 28	ii, 27
Pectoral (left/right)	8/9	8/9	8/8	–/8	10/10	8/9	9/8	8/8
Caudal	3/13/4	4/13/4	3/13/4	4/13/4	3/13/3	4/13/4	3/13/4	4/13/4
Total length	1,129	1,118	1,109	1,106	1,111	1,115	1,112	1,107
Length to—								
Origin of dorsal	267	246	248	248	265	251	235	239
Termination of dorsal (ray)	979	957	966	962	978	969	977	970
Termination of dorsal (membrane)	1,006	1,007	1,003	1,003	1,021	1,005	1,017	1,015
Origin of anal	484	482	482	481	484	471	471	511
Termination of anal (ray)	960	960	965	965	979	974	966	962
Termination of anal (membrane)	1,000	1,013	1,013	1,010	1,021	1,021	1,010	1,015
Origin of pectoral	192	188	167	175	180	181	184	175
Origin of ventral	173	170	161	159	146	149	157	147
Vent (middle)	457	471	466	468	466	448	457	499
Length of—								
Longest dorsal spine	46	53	48	58	53	54	51	49
Last dorsal spine	46	45	47	56	53	52	51	49
Dorsal ray	54	54	59	63	54	55	54	52
Longest anal ray	46	49	50	58	52	50	52	50
First anal ray	36	38	34	34	38	34	39	40
Last anal ray	44	47	48	56	52	48	50	49
Pectoral (whole fin)	46	43	39	38	42	37	41	37
Longest (*nth*) pectoral ray	27(6th)	25(6th)	29(6th)	22(5th, 6th)	24*(8th)	24(6th)	23(6th, 7th)	20(6th)
Inner ventral ray	115	105	111	98	99	99	104	98
Outer ventral ray	88	91	95	80	85	84	86	82
Head with opercular lobe	226	214	215	200	193	208	208	219
Head without opercular lobe	192	178	180	160	185	178	167	182
Snout	35	34	31	32	28	37	29	26
Eye	54	56	55	48	45	50	47	47
Interorbital	23	24	21	22	28	25	27	20
Depth—								
Maximum	154	149	154	147	138	134	131	151
At opercular border	121	112	127	120	122	110	104	125
Before anal origin	127	145	129	128	132	131	128	127
At middle of tail	107	127	116	112	122	118	110	115
Of caudal peduncle	46	54	48	52	48	47	51	45
Thickness—								
Maximum	81	72	93	77	101	102	78	100
Behind pectoral base	73	71	90	64	87	81	63	82
Before anal origin	54	54	58	63	56	55	54	70
At middle of tail	42	36	28	32	28	29	29	49

* In Part XIV (1966:113) the absolute length (0.9 mm) is correctly recorded but the *TLs* value is incorrectly given as 54. Some additional measurements of specimen (*e*) have been made expressly for this Table.

Genus **BREONA** *gen. nov.*

Diagnosis.—Body elongate, moderately compressed; no developed scales outside lateral line; but skin beset, particularly posteriorly, with very numerous, well separated, minute (several microns in diameter) apparently discoidal elements which may be squamous vestiges or rudiments. Lateral line present, comprising an anterior portion, composed of contiguous tubules, rising shortly behind head almost to dorsal profile, and running back near, and subparallel to, profile to, or a little beyond, level of vent, and a posterior portion, consisting of

a row of upwards of a score of spaced scales, originating about vertically below end of tubular portion, and extending back along midlateral line to at least middle of tail. Head moderate, subconical; operculum unarmed, its membrane united with upper part of pectoral and/or body immediately adjacent to fin, the lobe not, or negligibly, notched; preoperculum subcutaneous; anterior nostril tubular; posterior nostril a simple opening, well within the interorbital area; some open pores on dorsal and lateral surfaces; eye in anterior half of head, superolateral or superior; interorbital much less than eye diameter; gill membranes united, forming a free fold across isthmus; teeth in jaws stout, conical, in a band anteriorly, narrowing to become biserial or uniserial behind; teeth on vomer stout, conical, in a patch. Dorsal composed of numerous spines and one posterior ray, commencing shortly in advance of level of vent, united with caudal; anal with two spines and numerous rays, united with caudal; pectoral moderate, longer than eye, with stout unbranched rays, base of fin covered by branchiostegal membrane and operculum; ventral of three rays, the anterior small, wholly embedded in thick integument, fins inserted in median notch of ventral fold of common gill membrane; caudal with about a dozen rays, most, or all, unbranched. Male with intromittent organ; fish presumably viviparous.

Haplotype.—Breona greeni sp. nov.

Range.—At establishment of the genus its known provenance is northern Tasmania.

Affinities.—Discussion of the affinities of the new genus calls for some preliminary consideration of the standing and relationships of existing genera. Four genera with Australian representives are mentioned in the Check-List (McCulloch, 1929) in the Ophiclinidae: (*i*) *Ophiclinus* Castlenau, 1872 (emended in 1873 by Castelnau to *Ophioclinus*), (*ii*) *Neogunellus* Castelnau, 1875, (*iii*) *Scleropteryx* Ogilby, 1894, (iv) *Stenophus* Castelnau, 1875: of these, (*ii*) is treated by McCulloch as synonymous with (*i*). Whitley (1941: 39) has identified *Ophiclinus gracilis* Waite, 1906 with *Stichārium dorsale* Günther, 1867, the Ophiclinidae thus becoming the Stichariidae; hence it is needful here to take account also of *v Stichārium* Günther, 1867, (*vi*) the closely allied *Notograptus* Günther, described in the same paper, (*vii*) *Blanchardia* Castelnau, 1875, synonymized in the Check-List with *Notograptus* (in the Check-List the genera (*v*)-(*vii*) are treated as the Notograptidae, emended by Whitley to Stichariidae, *Stichārium* having line priority over *Notograptus*). From *Ophiclinus* as understood in the Check-List Whitley (1932) has separated off (viii) *Ophiclinops*, with *Ophiclinus pardalis* (McCulloch & Waite, 1918 as haplotype: however, as suggested previously in these Observations (1966: 113) *Ophiclinus varius* McCulloch & Waite, 1918 would seem to be a congeneric form—a view arrived at independently, and earlier, by T. D. Scott (1962: 250). The status of *Ophiclinus vis-à-vis Stichārium* has already received some notice. The identification of the two genera would certainly solve some problems. However, there would appear to be some difficulty (Scott, 1965: 61) in synonymizing *S. dorsale* with *O. gracilis*, as proposed by Whitley; possibly Günther's species is to be identified with some other Ophiclinid given in the Check-List, or it may of course simply be a species of *Ophiclinus* not since encountered (*O. aethiops* McCulloch & Waite, 1918, Tasmanian examples of which are reported in the present paper, has apparently remained uncollected for nearly half a century). One feature noted for *S. dorsale*, 'ventrals much larger than the pectorals', would be well met by either species of *Ophiclinops*, in which genus ventral is much more noticeably larger than (2-3 times as long as) in any recognized species of *Ophiclinus, s. str.*: however, ascription to *Ophiclinops* is clearly negated by Günther's generic 'anterior part of lateral line distinct . . .'.

Of the 8 genera above, 4 only appear to be represented by species currently recognizable—*Ophiclinus, Ophiclinops, Scleropteryx, Stenophus*. *Breona* stands well clear of each of these. From *Ophiclinus, s. str.*, it differs in, among other features, (*a*) more dorsal location and greater extent of tubular portion of lateral line; (*b*) much more caudad origin of dorsal (near vent instead of above head); (*c*) absence of developed scales except as elements of the second lateral line; (*d*) the superolateral eyes: from *Ophiclinops* in possessing an anterior tubular portion of lateral line, in more caudad origin of dorsal (in *Ophiclinops* behind head by less than half postorbital head) and in characters (*c*) and (*d*): from *Scleropteryx* by presence of pectorals, later origin of dorsal ('commences a short distance behind the opercular flap'), presence of a single dorsal ray (in *S. devisi* 3 rays), nature of lateral line ('a single lateral line along the middle of the body, straight'), in (*d*) and probably in (*c*): from *Stenophus* by presence of ventrals, nature of lateral line system ('several lateral lines, emitting no lateral branches'). [It may be remarked that in describing his *Ophioclinus devisi*, and in hesitating about—and finally deciding against—De Vis' manuscript name *Scleropteryx*, since generally accepted, Ogilby (1894: 374) observed, 'The neglect of Castelnau to even mention the pectorals is negative evidence as to their existence in his genus', *i.e., Ophioclinus*, the emended version of the 1872 *Ophiclinus*. However, in the description of the genotype, immediately following the account of *Ophioclinus*, it is noted (1873: 70) 'pectorals much shorter than the ventrals'.] *Neogunellus* (the original diagnosis of which contains some inconsistencies, *e.g.*, 'the ventrals jugular, composed of five rays', 'these' [the ventrals] 'are long, filamentary, and formed of two articulated rays') was identified with *Ophiclinus* by McCulloch & Waite (1918: 54), who further suggested the probable synonymy of its type species, *N. sulcatus*, with *O. antarcticus* Castelnau, 1872, and described, and figured the anterior portion of, a specimen labelled *Neogunellus sulcatus* (possibly in Castelnau's handwriting) from the old collection of the Australian Museum. This identification of *Neogunellus* with *Ophiclinus*, adopted in the Check-List, has received general acceptation. From the *Neogunellus* of Castelnau's original account *Breona* is distinguished by the more posterior dorsal insertion (fin 'beginning on the line of the end of the opercule'), by absence of small scales covering body; and probably by character of the lateral line, absence of canines in lower jaw, position of eyes, and other characters. From *Stichārium*, as far as

can be determined from the short accounts of the genus and the haplotype, our genus can be differentiated by having teeth on the palate, by not having 'ventrals much longer than pectorals', by (if original diagnosis can be relied on) possessing one dorsal ray. From *Notograptus* (with which the Check-List synonymizes *Blanchardia*) the Tasmanian fish differs trenchantly in not having lateral line 'complete, running along the base of the dorsal fin', in lacking a barbel at the symphysis of the jaw.

The more caudad origin, compared with that in the well known Ophiclinids, of the dorsal—the fin beginning just anterior to the vent, instead of over, or quite shortly behind, the head—is a striking feature. The character is formulated quantitatively in Table III, which gives, for *Breona greeni* and for several species of *Ophiclinus* and *Ophiclinops*, the lengths, as *TLs*, of the dorsal and anal bases, and the value of the ratio of the length of the dorsal base to that of the anal base.

Generic name.—*Breona* is one of the four words for fish (in a general sense) found among the scanty records of the several dialects of the extinct Tasmanian aboriginals, being given in a vocabulary by Roberts that appears, pooled with other small words lists by Gaimard, La Billardière, Péron and others, in Ling Roth (1899, app. B: vii). No indications of pronunciation are supplied; but the place-name Breona, used for a small settlement at the northern end of the Great Lake, is customarily pronounced as a trisyllable, with the *o* accented, long.

Breona greeni sp. nov.
(Figure 3)

Diagnosis.—The general characters those of the genus. D. xxxviii, 1-xli, 1. A. ii. 35-36. V. 3. P. 8-9. C. 12 (main rays). Br. 5. Dorsal originating behind head by a distance exceeding postorbital head, length to origin from two and a half to three times in standard length. Anal originating in advance of level of fifth dorsal ray. Posterior (formally inner) ventral ray with an external membranous fringe. Pectoral rays resembling ventral rays, the septa appearing as conspicuous annuli. Head subequal to trunk. Snout less than eye. Eye about six to seven in head; twice, or more than twice, interorbital; cutting dorsal profile; looking outward and upward. Lower jaw slightly longer than upper. Maxillary to below hind half of eye. Anterior lateral line with about 40 tubules, superior, extending about to level of vent; posterior a mediolateral line of spaced scales.

Types.—Holotype: a female, 63.4 in standard length, 68.2 in total length, from Green's Beach, Devon, Tasmania; collected by Mr R. H. Green, 4th May, 1965; Queen Victoria Museum Launceston Reg. No. 1966/5/10. Paratypes: female, *Ls* 65.2 *Lt* 70.1; male, *Ls* 57.3, *Lt* 62.0; locality and collector as for holotype, 18th, 19th December 1965; Queen Victoria Museum Reg. Nos.: 1966/5/11, 1966/5/12, respectively.

General description.—The description below is based on the holotype, variations exhibited by the paratypes being regularly noted in parentheses, the paratype cited first being the female.

Head 1.04 (0.98, 0.87) in trunk, which is 3.15 (3.08, 4.08) in tail without caudal.

Elongate, maximum depth 9.2 (10.8, 9.9), depth at origin of anal 12.0 (11.2, 11.5), depth, without caudal ridges, at hypural joint 32.5 (32.6, 30.2), in *Ls*. Moderately compressed anteriorly, greatly posteriorly; maximum thickness 14.1 (15.5, 17.4), thickness at origin of anal 21.5 (21.7, 19.1), thickness at hypural joint 317 (338, 287), in *Ls*. Thickness in depth: maximums 1.53 (1.44, 1.76), at anal origin 1.80 (1.93, 1.67), at hypural 9.75 (10.4, 9.50).

Head deeper than wide at opercular border, tapering tolerably evenly to tip of snout; in lateral view upper surface almost straight to level of middle of eye, somewhat convex between eyes, then descending rather steeply, but briefly, to upper lip, which is set high; the dorsum as a whole almost flat transversely, gently rounded laterally. Eye in anterior part of head, combined eye and snout 3.1 (3.0, 2.9) in postorbital head; set superolaterally, almost superiorly, constituting part of the dorsal profile; 1.4 (1.3, 1.8) times snout; 2.4 (2.6, 2.1) times interorbital; orbital rim somewhat elevated. Lower jaw slightly longer than upper. Mouth cleft oblique. Maxillary moderately expanded, evenly rounded distally; extending to level of 0.6 (0.7, 0.9) of eye. Anterior nostril tubular, tapering somewhat distally, its height twice, or more, its basal diameter; inserted on dorsal surface behind posterior border of upper lip by a distance subequal to its height; at, or a trifle above, horizontal level of middle of eye; internarial exceeding direct distance from nostril to orbit. Posterior nostril an opening rather larger than paired pores nearby; its margin slightly (or not observably) elevated; set hard against the eyeball, about halfway between anterior nostril and level of posterior border of eye. Pores on dorsum of head include a pair about midway between the anterior and posterior nostrils; an azygous pore at level of posterior orbital border; directly behind the last-named a pair, each approximately on the anteroposterior line passing through the middle of the pupil; behind these, by a distance subequal to their distance from snout tip, a proconçave arc of 5, the outer pair lying at (in paratypes close to) the external border of the conspicuous, sharply delimited light-colored middorsal stripe: on each side of the head at least 2 pores lie behind the posterior border of the preoperculum: pores are made out with difficulty in our material, and it is not unlikely others occur. Preopercular margin subcutaneous. Operculum unarmed; its membrane attached to upper part of pectoral (and/or body immediately adjacent), the membrane margin broadly rounded, not, or negligibly, notched superiorly. Branchiostegals 5. Gill membranes free of isthmus, joining broadly across it, about at level of preopercular border. Teeth in lower jaw stout, conical, some slightly recurved; in a broad lunule, mesially with 4-5 rows, narrowing to biserial or uniserial laterally. Teeth in upper jaw stout, conical, some slightly recurved, rather larger than mandibular teeth; in two bands, not, or barely, contiguous mesially; each band 3-4 wide anteriorly, narrowing posteriorly to a biserial, or shortly uniserial, termination at about the hinder two-thirds of the jaw. Teeth on vomer stout, conical; disposed irregularly in a largish ovoid patch.

Lateral line comprising a conspicuous anterior and a rather obscure posterior section. Anterior section a series of about 40 contiguous tubules, originating in last one-third of head, a little in advance of level of pectoral insertion, at about one-third (half, two-fifths) of an eye diameter below dorsal profile; rising in first 10 or so tubules almost to dorsal profile, and extending back—in a line grossly very slightly convex upwards, with contiguous tubules in some cases collinear, in other cases set at a variable small angle to each other, giving rise to a series of small-scale waves or zigzags—to level of vent, beyond which 2 or 3 tubules, curving downward somewhat, continue it to horizontal level, on left side, of 1st, on right side, of 2nd anal spine (left and right, 2nd anal ray; left 3rd, right 2nd anal ray); its length (left side) 1.58 (1.46, 1.42) times head. Posterior section apparent to naked eye as a line of small inconspicuous regularly spaced lightish spots on midlateral surface of tail, originating below, and shortly behind, last tubule of anterior segment and extending back almost horizontally towards the caudal; pores in anterior two-thirds, or more, of tail occurring at about 1 per myomere, behind which they may be more widely set (total number of caudal myomeres *ca* 40). Examination of a strip of skin dissected off from the right flank of the larger paratype, at 0.5-0.7 of the length behind the vent (without caudal) shows the apparent spots, here 800-850μ apart, are well developed cycloid scales about 180μ in diameter (Fig. 3*b*): these are similar in general shape and size to ordinary body scales on the hind flank of a specimen of *Ophiclinops varius* about half the overall size of the paratype.

No scales other than the series along the lateral line have been detected. However, under a Zeiss F objective, with a medium ocular, the whole surface of the skin is seen to be crisscrossed regularly with minute, fairly closely set longitudinal and transverse striae, at most of the intersections of which occur more or less discoidal structures that may possibly represent squamous rudiments or vestiges.

Dorsal xxxix, 1 (xxxviii, 1; xli, 1); arising rather gradually, the early spines being more or less markedly decumbent, making somewhat difficult the determination of the exact point of origin; behind the first few spines, the profile rising almost rectilinearly to near the middle of the length, then falling in a very gentle, upwardly convex curve; some spines projecting beyond membrane; middle spine about 12 in head; maximum vertical height of fin about one-third eye diameter; ray noticeably longer than last spine, about 7 (7, 8) in head, less erect than neighboring spines, approaching horizontal, its tip, contained within membrane, in advance of level of hypural joint by about half depth of body (without fin) vertically below it; fin originating a little in advance of level of vent, length to origin contained 2.72 (2.65, 3.01) in remainder of standard length; base (measured to base of ray) 1.68 (1.69, 1.61) in *Ls*, or 3.17 (2.97, 3.37) times head; membrane wholly continuous with caudal, the fin profile dipping slightly at the point of junction. Anal ii, 35 (ii, 35, ii, 36); originating below 3rd (2nd, 3rd) dorsal spine, behind head by 1.14 (1.04, 0.92) times head; base (measured to base of last ray) 1.77 (1.76, 1.65) in *Ls*, or 3.02 (2.85, 3.27) times head, or 1.06 (1.01, 1.03) times dorsal base; 1st spine rather more than half 2nd, the latter nearly two-thirds 1st ray; border of fin more or less parallel with ventral body profile; middle ray a trifle less than twice length of middle dorsal spine, but, as preserved, anal rays are set more obliquely than dorsal spines, the vertical heights of the two fins being subequal; last ray inserted behind dorsal ray, the latter almost opposite penultimate anal ray; fin continuous with caudal, the junction indicated by a slight notch; rays with strong and conspicuous septa, modally about 10. Ventral 3; short, carried forward, reaching to below eye, carried back, extending 0.29 (0.28, 0.28) of distance to vent; originating just posterior to free border of common fold of gill membranes, between levels of borders of preoperculum and operculum, length to its origin 1.7 (1.6, 1.7) in head; anterior ray wholly enclosed in membrane, hidden, its length about two-fifths length of middle ray; middle ray a little shorter than, rather stouter than, the posterior (formally inner), their lengths 2.5 (2.7, 2.3), 2.4 (2.6, 2.1) in head; free rays projecting for about a quarter of their length beyond the middle of the bight of the membrane joining them; posterior ray with, throughout its proximal four-fifths, a fairly wide external slip of membrane (not developed in species of *Ophiclinus* and *Ophiclinops* examined). Pectoral 8 (left), 9 (right) (8, 8; 8, 8); broad, short, auriform, 1.8 (1.9, 1.7) in head, or 3.8 (3.5, 3.5) times eye; upper part of base hidden by opercular flap, with which it is more or less definitely conjoined; lower part of base overlapped by branchiostegal membrane; originating behind ventral origin by little more than basal diameter of ventral; length to origin 1.2 (1.2, 1.2) in head; rays simple, as preserved characteristically curved forward and upward, tips rounded, free of membrane, which is deeply scalloped; septae numerous (in a median ray 30, or upwards), in the form of closely set rings, giving the ray an annulated appearance similar to that of the ventral rays. Caudal 12 main rays, all unbranched (some indication of possible terminal fission in a couple of median rays in a paratype), and 5 + 5 (4 or 5 above and below) procurrent rays; short, its length 2.5 (2.7, 2.3) in head; as preserved, narrow, its margins continuing those of the dorsal and anal to end in a point, but opening out to give rounded posterior border.

Color pattern.—(*i*) *Holotype.* Body: whole of dorsal surface covered by a conspicuous stripe of light fawn, this uniform band, the borders of which are sharply delimited, invading the side, occupying the upper one-sixth of the flank anteriorly, but decreasing regularly in depth posteriorly to become a thin line at caudal origin; flank between stripe and vicinity of midlateral line dusky olivaceous, darker than lower half; the distinction less marked on the trunk, which further differs from the tail in having the dusky area decreased in depth by the continuation upward, immediately behind the head, to level of upper part of pectoral base, of the immaculate, somewhat yellowish flesh of the belly; the duskiness noted is due to brownish longitudinal somewhat wavy streaks, formed of closely set punctulations, mostly running somewhat obliquely, down and back on upper part of flank, up and back on lower part, the punctulation becoming more general and more confused in last one-third of tail; beginning at level of lower border of eye

and ending equidistant from dorsal and ventral profiles, a conspicuous line of about a score (number and disposition somewhat different on the two sides) of black markings, mostly in the form of short lines, the last 4-5 rounded; about a dozen similar but smaller markings between the main series and the dorsal profile, mostly nearer the latter. Head: behind eyes, dorsum and side down almost to level of inferior border of orbit occupied by the forward continuation of the conspicuous dorsal body stripe; except for upper lip and lower part of operculum, which are largely whitish, immaculate, the whole of rest of head olivaceous, heavily marked with brownish, the punctulation mainly diffuse on upper part of operculum, forming small patches and vermiculations elsewhere, with more or less clear indications of 5 short radial spokes from eye. Dorsal fin: membrane in anterior half largely concolorous with the fawn dorsal stripe, this invasion of pigmentation from the body gradually decreasing to extinction caudad, the rest of the membrane greyish; spines glassy, their exposed tips clear. Anal, pectoral, ventral whitish, immaculate. Caudal chiefly olivaceous, a trifle darker near ends of middle rays; confusedly punctulated with dark grey and brownish, the pigmentation stopping short of tip and sides, the latter being chromatically continuous with the ends of the dorsal and anal.

(ii) *Paratypes.* The chief variations exhibited by the larger paratype (another female) are: dorsal stripe somewhat greenish yellow; ground color of side darker, the upper and lower regions less clearly differentiated than in holotype; brownish longitudinal streaks darker and in general rather wider; vermiculations on head less conspicuous; no spokes from eye; dorsal with some small, irregular, rather faint groups of brownish punctulations on anterior half of membrane, and 3 brownish spots in posterior half; caudal tip white, preceded by a very narrow black bar. The smaller paratype (male) has the ground color much the darkest; no brownish longitudinal streaks, which have perhaps become indistinguishable by mere extension; on flank, particularly in lower half, a number of small light areas, often rounded, which may represent positive elements of pattern, or may simply be uninvaded regions of ground color; some brownish clouding proximally on membrane of last 6-7 dorsal spines; 3 short dark spokes and 4 lighter, longer less sharply defined streaks from orbit; most of caudal dark brownish, centrally approaching blackish, but a very narrow whitish border at tip, along whole of upper, and part of lower, margin.

Life colors.—(*i*) *Holotype.* The fairly fresh holotype had the ground color light, somewhat greenish yellow, deeper on upper part of flank, approaching white on lower side of trunk and on ventral surface; longitudinal streaks pinkish red; markings along midlateral line green; dorsal stripe off-white, contrasting boldly (as in preserved specimen) with rest of fish; eye with much gold, ocular spokes reddish; dorsal pinkish, largely fringed lighter; anal pale, approaching white; pectoral and ventral whitish; caudal with some reddish.

(*ii*) *Paratypes.* The following notes summarize extensive observations made on the coloration of the 2 paratypes. Female: dorsal stripe uniform pale orange; general color of sides olivaceous, tending to become more greyish in upper portion and posteriorly; longitudinal streaks brownish olivaceous; markings in a line along side dark brown; belly whitish with bluish tinge; side of head below the dorsal stripe mostly orange, deepest just below and behind eye; lips whitish, the lower with 4 or 5 small greyish patches on each side, an extension of this series involving the chin; operculum silvery, with half a dozen subhorizontal wavy lines, a little narrower and lighter than those on front of trunk; tubes of anterior nostrils medium brown; a narrow light interorbital cross bar about at level of front of pupil, rest of interorbital dark, almost black, sharply delimited both in front and behind; ventral surface of head pale orange anteriorly, silvery posteriorly; chin whitish, with a touch of bluish, and some greyish patches noted above; dorsal fin orange proximally (the color continues with that of the dorsal stripe), whitish distally, the orange forming a subtriangular area, deepest anteriorly, in each interradial, small blackish smudges on membrane at spines 22/23, 34/35 and (less pronounced) 38/39; anal wholly white; pectoral pale flesh, immaculate; ventral pale yellow, immaculate; caudal centrally yellowish, orange, blackish, in succession caudad; a patch of blackish in upper part of base; elsewhere, except for colorless borders, yellow. The male differed, when fresh, from the female chiefly as follows: dorsal stripe rather paler; ground color more greyish; longitudinal streaks much less obvious, their interspaces being largely filled with fine crowded punctulations; on trunk streaks lost, the whole region, down almost to ventral profile being pale yellowish, being finely punctulated with brown; markings along midlateral line in the form of shorter, somewhat thicker dashes, with the last 4-5 rounded; behind vent on flank some obscure small whitish spots; sinuous lines on operculum replaced by a few brownish blotches; brown markings on side of head and greyish patches on chin larger, more discrete, darker; anterior nostrils very pale brownish; light and dark cross bars between eyes less distinct; posterior part of dorsal fin more whitish; caudal mostly blackish, darkest posteriorly, rather narrowly margined behind and at sides with white.

Intromittent organ.—The intromittent organ of the male paratype (Fig. 3c) is extruded. Its total height is rather less than its transverse basal diameter; about half length of a modal anal ray. Viewed from below, it presents a close approximation to a short ellipse, the anterior half of the periphery being a little more strongly curved than the posterior half; major axis transverse. In front elevation the main mass is made up of a basal portion in the form of the frustrum of a cone (widest distally) and on outer portion resembling the pileus of a mushroom. In lateral view, the anterior profile first rises steeply, barely convex, and then curves back to join the boldly curved posterior profile, the point of junction occurring at the level of the anterior one-third of the anteroposterior extension of the base. At the point of junction the pale yellow main mass, which alone has been considered so far, is surmounted by a small colorless conical process directed downward and forward, its tip extending almost to level of anterior face of the supporting structure. The organ, which is marked by some subvertical plicae, emerges from an aperture fringed, for rather more

than its anterior half, by a strongly plicate fold, highest mesially.

Proportions as TLs.—Some dimensions of the holotype and the 2 paratypes, given as thousandths of standard length, are set out in Table VII.

Secondary sexual dimorphism.—In an investigation of *Ophiclinus aethiops* McCulloch & Waite, 1918, discussed elsewhere in this paper, the relative precaudal length of females was found to be significantly greater than that of males. In the types of *Breona greeni* the precaudal length of the females is 38.3% (holotype), 39.6%, that of the male 34.6%, of *Ls;* the male value being less than the female mean by 11.3% of the latter (in *O. aethiops* 8.5%): while for trunk the corresponding entries are 19.6%, 19.5% 16.1%, male deficit as before 17.8% (*O. aethiops* 15.0%). Variations, concomitant with those of trunk and tail, of the vertical fin bases in the sexes are exhibited in Table III, and receive some notice in the observations on *O. aethiops.*

Distribution.—The species is at present known only from the type locality.

Trivial name.—The trivial name is in honor of Mr R. H. Green, Zoologist, Queen Victoria Museum, Launceston, whose enthusiastic collecting of rock-pool fishes at Green's Beach, Devon has led to the addition to the Tasmanian list of a number of species, and has provided much other valuable material, the examination of which is serving to extend considerably our knowledge of the local fish fauna.

TABLE VII

Breona greeni gen. et sp. nov. Meristic data, and dimensions, expressed as thousandths of standard length (*TLs*), of holotype and 2 paratypes from Green's Beach, Devon, Tasmania, collected by Mr R. H. Green

Count or Dimension	*Specimen (sex; standard length, mm.)*		
	Holotype ♀ 63.4	*Paratype* ♀ 65.2	*Paratype* ♂ 57.3
Dorsal	xxxix, 1 ii, 35	xxxviii, 1 ii, 35	xli, 1 ii, 36
Anal	8/9	8/8	8/8
Pectoral (left/right)	3	3	3
Ventral	12 + ⅝	12 + ⅛	12 + ¾
Caudal	1076	1075	1082
Total length	368	377	332
Length to dorsal origin	963	968	953
Length to dorsal termination (base of ray)	402	406	356
Length to anal origin	968	975	962
Length to anal termination (base of ray)	156	172	150
Length to pectoral origin	110	124	106
Length to ventral origin	383	396	346
Length to vent (middle)	16	16	16
Length of longest dorsal spine	28	29	24
Length of dorsal ray	28	31	30
Length of longest anal ray	102	104	108
Length of pectoral (whole fin)	73 (3rd)	74 (3rd)	70 (4th)
Length of longest (*n*th) pectoral ray	32	31	35
Length of anterior (hidden) ventral ray	76	74	80
Length of middle ventral ray	80	77	84
Length of posterior (formally inner) ventral ray	297	291	262
Length of tubular section of lateral line	188	199	185
Head	19	20	17
Snout	27	30	31
Eye	11	8	8
Interorbital	109	93	101
Depth, maximum	84	89	87
Depth, at vent	31	31	33
Depth, at hypural joint	71	66	58
Thickness, maximum	47	46	52
Thickness, at vent	3	4	4
Thickness, at hypural joint			

Family TRIPTERYGIIDAE

Prior to the appearance of the Check-List there were reported from Tasmania (*i*) *Tripterygion clarkei* Morton, 1888 (Morton consistently spelt the generic name *Triptergium*: Fowler (1953: 264) gives the trivial name, from Clarke Island, as *clarkii*), referred in the Check-List (McCulloch, 1929: 348) to *Gillias* Evermann & Marsh, 1900, and now placed by Whitley (1964) in *Norfolkia* Fowler, 1953, a step contemplated, but not taken, by Fowler; the species being known, outside the two original notices of it (Morton, 1888: xlvii, 78), only from a

paper by Hall (1913) who gave an account of some twenty specimens from Hobart that he ascribed to this form: (*ii*) a Tripterygiid in the possession of R. M. Johnston that was mentioned at the Royal Society's meeting at which Morton's specimen was exhibited, and that is perhaps the subject of a short entry in R. M. Johnston's Memoranda, redacted by Whitley (1929: 165), by whom it is referred to Morton's species, from which, however, it has a decidedly different dorsal formula, D. 21/8 (presumably iii, xviii, 8; contrast iii, xvi, 11): for further details see Scott (1939 159). In 1939 the writer reported from the mouth of the Currie River, Dorset, a single individual of *Tripterygium macleayanus* Lucas, 1891, since referred by McCulloch to *Gillias* and by Whitley to *Norfolkia*. *Brachynectes fasciatus* Scott, 1957, hitherto known only from South Australia, is added here to the local list, and some descriptive observations on it are given: several points in the original account require emendation.

KEY TO TRIPTERYGIIDAE RECORDED FROM TASMANIA

In the compilation of a key to the Tasmanian members of the family the best that can be done with R. M. Johnston's unidentified specimen is to segregate it from the rest on number of dorsal rays: it is doubtful whether its generic status can now be satisfactorily established. The possibility that *Norfolkia clarkei* is conspecific with *N. macleayanus* cannot be wholly ruled out.

1 { Second dorsal with 18 spines. Third dorsal with 8 rays .... R. M. Johnston's specimen
1 { Second dorsal with < 18 (10-16) spines. Third dorsal with > 8 rays (10-19) 2

2 { Number of spines of second dorsal < number of rays of third dorsal. Superior lateral line ending below second dorsal. Inferior lateral line a series of incised scales behind upper .... *Brachynectes fasciatus*
2 { Number of spines of second dorsal > number of rays of third dorsal. Superior lateral line ending below third dorsal. Inferior lateral line ? 3

3 { D. iii, xiv-xvi, 10. Lat. l. 34. Maxillary teeth subequal .... *Norfolkia macleayanus*
3 { D. iii, xvi, 11. Lat. l. 26. Some maxillary teeth enlarged .... *Norfolkia clarkei*

Genus **BRACHYNECTES** Scott, 1957

Brachynectes fasciatus Scott, 1957

Brachynectes fasciatus Scott, 1957, *Trans. Roy. Soc. S. Aust.*, **80**: 180, fig. 1. Type locality: Pelican Lagoon, Kangaroo Island, South Australia.

Verconectes fasciatus (Scott), Scott, 1962, Marine and Fresh Water Fishes of South Aust.: 255; unnumbered fig. on p. 256.

Material.—Tasmanian material examined comprises 1 specimen (*g*), *Ls* 36.1, *Lt* 44.6 from a large collection of intertidal rock-pool fishes made at Green's Beach, Devon by Mr R. H. Green on 4th, 5th September; 6 specimens (*a*)-(*f*), *Ls* 24.9, 31.1, 33.2, 34.0, 34.8, 35.3, *Lt* 31.0, 38.5, 41.6, 41.5, 43.1, 43.7, same locality and collector, 18th, 19th December 1965. Through the courtesy of the authorities of the South Australian Museum, Adelaide the following specimens from South Australia have been examined: 1 specimen (*h*), *Ls* 31.1, *Lt* 38.6, collected at Cape Jervis by T. D. Scott on 6th November 1956 (printed entry on label 'Id by T. D. Scott'; metal tag in phial F 2933); 5 specimens, *Ls* 28.7, 32.3, 33.1, 39.9, 42.0 (in poor condition, very rigid, most with caudal imperfect), collected in Port River, Adelaide by A. Zeitz on 12th February 1931 (F 1488).

Tasmanian record.—Specimen (*g*) provides the first record of this species in Tasmania.

Distribution.—Scott (1962: 256) observed 'To date, this species has been taken only in shallow weedy areas in Pelican Lagoon, Kangaroo Island, and on the coasts of that island'. However, the localities recorded for the South Australian examples we have received on loan, specified above, would indicate a wider South Australian distribution than thus allowed for.

Generic status.—*Brachynectes* was stated in the original diagnosis to be 'Separated from other Australian genera in having the second dorsal fin shorter than the third'. However, its author later (1962: 255) referred its type species to *Verconectes* Whitley, 1931, proposed as a substitute name for *Trianectes* McCulloch & Waite, 1918, considered to be preoccupied by *Trinectes* Rafinesque, 1832. In his recent list of Australian fishes Whitley (1964) continues to recognize *Brachynectes* (with sole species *B. fasciatus*). The retention of the genus seems advisable. *Verconectes* is noted by its author as differing from his *Vauclusella* (orthotype *Tripterygium annulatum* Ramsay & Ogilby, 1888), described earlier in the same paper, by, among other features 'the very long anterior portion of the lateral line'; which in *Verconectes bucephalus* reaches to, or a trifle beyond, level of middle of third dorsal. In *B. fasciatus* this section of the lateral line does not extend beyond level of end of second dorsal. Other differences between the two species that may be of generic value include the excess in *Brachynectes* of length of the third over the second dorsal on which original emphasis was placed (in *V. bucephalus* the excess of the second over the third is of comparable magnitude); the character of the pectoral rays (all simple in *Brachynectes*, upper divided in *Verconectes*); possibly the structure of the ventral (see below), and perhaps the gross form of the mouth. With his account of *Brachynectes* Scott gave a key to the genera of Tripterygiidae of Australia, covering, in addition to the new genus, *Lepidoblennius* Steindachner, 1867, *Helcogramma* McCulloch & Waite, 1918, *Gillias* Evermann & Marsh, 1899, *Notoclinops* Whitley, 1930, *Verconectes* Whitley, 1931, *Vauclusella* Whitley, 1931, *Tripterygion* Risso, 1826. Fowler (1953) has discussed relationships of some Australian forms, in particular those placed by McCulloch in the Check-List in *Gillias;* with his *Norfolkia*, to which genus Whitley (1964) refers all 3 species referred in the Check-List to *Gillias*, together with *N. squamiceps* (McCulloch & Waite, 1916), *N. thomasi* Whitley, 1964.

Remarks on original account.—The first Tasmanian specimen obtained (*g*) fails to conform with the original description and figure in having (*i*) greater number of ventral rays, (*ii*) anal with two spines, (*iii*) second dorsal base shorter relative to third dorsal base, (*iv*) different course of superior lateral line, (*v*) both ctenoid and cycloid scales: it

was thought possibly to represent a new species. However, examination of further Tasmanian specimens and the South Australian material specified above—particularly the best-preserved example, (*h*)—has shown (*i*) though the original description gives V.2, there are regularly 3 rays in the ventral, the posterior being small, and usually being wholly enclosed in membrane; (*ii*) the original entry is A.20-21, but the first two anal radial elements are not articulated; (*iii*) from the figure, the ratio of the base of the third dorsal (between bases of rays) to that of the second dorsal (between bases of spines) is about 1.44; in our original local example it is 1.07, in the specimen (*h*) identified by T. D. Scott 1.15, in the 6 Tasmanian specimens (*a*)-(*f*) 1.07, 1.03, 1.12, 1.01, 1.21, 1.15, respectively—all examples thus having the discrepancy between the sizes of the fin bases less than depicted for the type; (*iv*) the tubular superior section of the lateral line runs almost exactly parallel with the dorsal profile (dropping in some individuals to become a trifle further from the profile posteriorly), and not, as in the figure of the holotype, rising rather sharply backward to have its termination about half as far from the profile as its origin [the figure correctly indicates that the origin of the line is about 2 scales ($\frac{1}{2} + 1 + \frac{1}{2}$) from the profile, but shows only $\frac{1}{2} + \frac{1}{2}$, instead of $1 + \frac{1}{2}$ or $\frac{1}{2} + 1 + \frac{1}{2}$, at its termination; the slope thus arrived at being rendered steeper by failure to take into account differences of size among the scales]; (*v*) scales are reported simply as ctenoid; this is the character of most scales, but those on the anterior breast are cycloid.

General description.—The following account is based primarily on the largest Tasmanian specimen, (*g*). Entries in square brackets relate to the 6 other Tasmanian examples, (*a*)-(*f*), and the South Australian (*h*). Entries in parentheses relate to all 8 lettered specimens.

D. iii, X, 13 [iii, X; third dorsal with 13 (4 specimens), 12 (3)]. A. ii, 19 [ii; rays 17 (1), 18 (5), 19 (1)]. P. (left/right) 13/13 [11 (1), 13 (6)/12 (2), 13 (4), 14 (1)]. C. 13 main rays [12 (2)]. V. 3. Br. 6. L. lat. (left/right) 11 + 19/12 + 19 [11-14 + 19-21, with some variation on right and left sides]. L. tr. 2 + 1 + 7 [scales below tubules 7 (3), 8 (4)].

Head large, 3.3 (2.6-3.4, $\bar{x}$ 3.09 ± 0.082), in *Ls*; subconical, its greatest width 1.1 in its greatest depth; naked, the body scales terminating along a sharply defined oblique line from base of 1st dorsal spine to upper angle of operculum, there being about 5 scales in advance of the latter. Eye in anterior half of head, not cutting dorsal profile; 3.6 (3.4-4.0, $\bar{x}$ 3.63 ± 0.077) in head; 1.1 (0.9-1.2, $\bar{x}$ 1.05 ± 0.035) times snout; 1.3 (1.3-2.0 $\bar{x}$ 1.58 ± 0.072) times interorbital, which is gently convex in front, almost flat behind. Jaws equal anteriorly (equal, or lower very slightly projecting); lips thick anteriorly, protuberant, the upper partly overlapped by free border of preorbital; mouth oblique, anterior end of cleft about on horizontal level of inferior border of pupil; maxillary much expanded posteriorly, its greatest width exceeding distance of its posterosuperior angle from orbit, extending to below posterior border (0.4-0.8, modally 0.8) of eye. Preoperculum with subvertical free posterior border, slightly behind level of 1st dorsal spine. Upper angle of operculum incised. Gill membranes united, free of isthmus. Anterior nostril tubular, a little higher than wide; equidistant from hind border of lip and orbit; surmounted by a subtriangular flap, longer than the cylinder, its gently convex terminal border very minutely crenulate. Posterior nostril a simple opening, with a low rim, almost directly behind anterior nostril, just posterior to level of front of eye. Supraorbital tentacle with its inner insertion partly on eye; basally a broad flap, compressed anteroposteriorly, a little wider than high, giving rise along its distal border to half a dozen subtriangular processes; total length subequal to diameter of pupil. Two minute rigid digitiform processes on either side of, and immediately in advance of, 1st dorsal spine; distance between them equal to anterior internarial. Numerous cephalic pores: these are of more than one size, and their systematic location presents some difficulty. The main concentrations of the larger pores are disposed as follows: (*a*) along border of preoperculum, where about a score lie mainly in 2 irregular rows; (*b*) a patch just behind eye; (*c*) an oblique band, 1-2 wide, from lower angle of (*b*) back towards upper end of preopercular border; (*d*) a cluster between (*c*) and front of first dorsal base; (*e*) 6-8 below eye; (*f*) about 8 on preoperculum; (*g*) a dozen on dorsal surface between tip of snout and origin of dorsal. Teeth in lower jaw villiform; in anterior half of jaw in a broad band, narrowing behind, at first rapidly, then more gradually. Teeth in upper jaw similar to those of lower jaw, and more or less similarly disposed, but the band initially not so wide, and decreasing in width more evenly. Three contiguous patches of villiform teeth on vomer. Palatines toothless. Gill membranes broadly united, free of isthmus.

Body stout; moderately compressed anteriorly, greatly posteriorly; its width behind pectoral base, at level of its maximum, at vent, at hypural joint 0.7, 0.9, 0.4, 0.2, respectively, of its depth there; maximum depth 4.0 (3.7-4.4, $\bar{x}$ 4.26 ± 0.058), depth at vent 4.1 (4.0-4.4, $\bar{x}$ 4.22 ± 0.019), in *Ls*. Except for pectoral base, body wholly covered with scales; in general rather large, smaller on belly and breast; anterior breast scales cycloid, others ctenoid; 32 [29 (2), 30 (2), 31 (1), 32 (2)] scales between axilla and caudal base, the latter overlapped on each side by 3 enlarged specialized scales—this is the regular pattern; exceptionally one scale is replaced by 2 or more smaller scales. Counted obliquely backwards from origin of first dorsal scales are 2 + 1 + 7 [for variants, see above], or from origin of third dorsal 2 + 1 + 4—for latter convention see Scott (1939: 153, footnote). Tubular superior segment of lateral line parallel with dorsal profile; left/right 11/12 contiguous tubules [variants above], the last beneath 8th [7th (2), 8th (4), 9th (1)] spine of second dorsal; lower segment consisting of 19 [variants above] scales, each with a deep *U*-shaped median incision in its posterior border, the depth of the incision in anterior scales being about equal to distance between front of one groove and back of next, and in posterior scales to half this distance, or less; first incised scale below [or just caudad of] end of last tubule; lines of tubules and incisions separated by $\frac{1}{2} + 1 + \frac{1}{2}$ scales.

Dorsals just connected by membranes basally; third attached by membrane to caudal peduncle. First dorsal originating slightly in advance of hind margin of operculum; length to origin 4.6 (3.9-4.9, $\bar{x}$ 4.39 ± 0.13) in *Ls;* base to back of 3rd spine) 4.1 (3.1-5.8, $\bar{x}$ 4.85 ± 0.27) in head; 1st, 2nd, 3rd spines 2.8, 2.7, 3.3 [1st spine 2.1-2.8 $\bar{x}$ 2.54 ± 0.091] in head; First pseudo-interdorsal (spine to spine) half eye. Second dorsal originating above hind face of pectoral base; length to origin 3.0 (2.7-3.0, $\bar{x}$ 2.84 ± 0.030) in *Ls;* base (spine to spine) 1.2 (1.2-1.4, $\bar{x}$ 1.25 ± 0.027) in head, or 1.08 [1.07, 1.03, 1.12, 1.01, 1.21, 1.15, 1.15) times base of third dorsal; 1st, 5th, 9th, 10th spines 2.8, 2.2, 2.5, 2.8 (1st spine 2.8-3.9, $\bar{x}$ 3.06 ± 0.16) in head. Second pseudo-interdorsal (spine to spine) two-thirds eye. Third dorsal with all rays simple; originating a little nearer end of head than base of caudal; length to origin 1.6 (1.5-1.6, $\bar{x}$ 1.53 ± 0.011) in *Ls*; base (ray to ray) 1.1 (0.8-1.2, $\bar{x}$ 1.09 ± 0.033) in head; 1st, 7th, 11th, 12th, 13th rays 2.5, 2.0, 2.5, 3.4 5.0 (1st ray, 2.5-2.8 $\bar{x}$ 2.63 ± 0.046) in head; last ray above penultimate anal ray; briefly attached by membrane to caudal peduncle at a point in advance of end of specialized caudal scales by a distance of little less than depth of body at that point; laid back, fin reaches beyond origin of specialized scales. Anal originating below 6th spine of second dorsal; length to origin 2.2 (2.0-2.2, $\bar{x}$ 2.04 ± 0.084) in *Ls;* base 1.4 (1.3-1.5, $\bar{x}$ 1.41 ± 0.025) times head; 1st spine, 2nd spine, 1st, 9th, 17th, 18th 19th rays 4.6, 3.8, 2.8, 2.3, 2.2, 3.4, 3.7 (1st spine 4.5-6.9, $\bar{x}$ 5.43 ± 0.091; 2nd spine 3.3-4.9, $\bar{x}$ 3.86 ± 0.050; 1st ray 2.5-3.1, $\bar{x}$ 2.83 ± 0.074) in head; last ray followed by mere slip of membrane; laid back, fin extends slightly beyond laid-back dorsal, almost to tip of specialized scales. Pectoral more or less pointed; all rays simple; originating behind level of ventral origin by a trifle less than snout length; length to origin 3.6 (3.6-4.1, $\bar{x}$ 3.76 ± 0.020) in *Ls;* base partly overlapped by transparent operculum; length of whole fin 0.9-1.2, $\bar{x}$ 1.01 ± 0.028 in head; longest, 8th [7th (3), 8th (3), 9th (1)] ray 4.1 times shortest, 1st, or 1.1 (0.9-1.2, $\bar{x}$ 1.01 ± 0.028) in head; adpressed, fin reaches beyond vent, to below last [last (2), penultimate (3), antepenultimate (2)] spine of second dorsal. Ventrals originating below angle of preoperculum, immediately behind free border of common gill membrane; length to origin 5.0 (4.4-5.2, $\bar{x}$ 4.90 ± 0.082) in *Ls*; 1st ray small, slender, wholly bound to 2nd [in specimen (*d*), right fin, free for most of length; in (*d*), left fin, and in some other cases, the needle-like tip free]; 1st ray 4.6 (2.9-5.6, $\bar{x}$ 4.18 ± 0.28), 2nd 1.6 (1.4-1.6, $\bar{x}$ 1.53 ± 0.070), 3rd 2.2 (2.0-2.2, $\bar{x}$ 2.11 ± 0.027) in head, the longest exceeding twice eye. Caudal rounded; all rays simple ['none of the rays bifurcate' (Scott, 1957: 181), but his fig. 1 shows 9 rays fairly deeply divided]; length 1.3 (1.2-1.5 $\bar{x}$ 1.33 ± 0.025) in head: base overlapped by a set of 3 subequal enlarged scales, their exposed length about one-fifth total length of fin; medial scale overlying the others [1 of the lateral scales sometimes replaced by 2, or more, smaller scales].

Coloration.—The colors in life have not been reported. The following notes summarize some observations made on specimens (*a*)-(*f*) on receipt, when some loss of color had clearly taken place, the extent of decolorization varying in individuals and at times in different parts of the one individual.

Upper half of operculum bright reddish or orange; lower half translucent, revealing pectoral base with conspicuous red area, peppered with black spots and having a black border. Rest of head a complex assemblage of lighter and darker areas, reddish, brownish, whitish, pinkish. yellowish, orange. Below eye some white, punctulated with brown, diffuse or forming lines. Alternate darker (reddish, bearing black spots) and lighter (pearly, immaculate) areas fringing operculum and preoperculum; the lighter often in the form of complete bays invading from the margin; upper 2 dark areas on operculum commonly sharply defined redbrown spots; markings on preoperculum extend downwards to border ventral surface, the region between them (isthmus and part of branchiostegal membrane) being off-white, without markings. Lower lip with about 10 such color bands, others of which occur also laterally on upper lip. Dorsum mostly orange or yellowish, fairly heavily punctulated with darker, but lacking discrete pattern. Anterior nostril white or pinkish, peppered minutely with red or brown. Superocular tentacle bright red or reddish brown, either without other color or somewhat splashed with brown.

Ground color of body probably originally orange, now best preserved and brightest in a band along dorsal profile; the conspicuous character of this region enhanced by absence, or virtual absence, of punctulation on the scales, which nearly everywhere else carry a dark brown arc concentric with border of preceding scale: in specimen (*e*), which is in general much darker than the others, almost all scales are so patterned. Along midlateral line 5-7 fairly evenly spaced dark spots (as preserved, the hinder the darker, more sharply delimited), within which may be small orange or bright red dots; last 2 may trespass upward somewhat on to the otherwise unmarked superior band, and may be clearly duplicated below midlateral line (either as separate spots or as part of a dumbbell); but others are not so repeated below, or are at most vaguely echoed by irregular areas, a little darker than ground color, that may occur vertically below them, or may be out of phase with them, coming to lie beneath their intervals. Belly whitish and/or bluish; some scales with some brownish blotching.

First dorsal overall reddish orange; 1st spine (which may be lighter than the rest) crossed by 3 red (immaculate or with minute black dots) bars sharply bordered with black, the interspaces whitish punctulated with blackish. Second dorsal crossed by 3-4 red bars, vertical or running upward and forward, subequal in width to their whitish interspaces; may also carry several small red spots partly bordered with black. Third dorsal much lighter in general appearance than second; mostly white, with delicate lines, running downward and backward, of orange, each line a series of small contiguous rectangles, occurring on both membrane and spines, many rectangles partly outlined by minute black splashes or dots. In the dark specimen (*e*) first dorsal is black with some red; second dorsal largely black with some proximal red; third dorsal proximally ashen, and, especially behind first 2-3 rays, distally blackish. Anal white; crossed by a dozen orange or yellowish bars, running down-

ward and forward, darkest proximally, wider than bars of third dorsal, much narrower than those of second dorsal; composed of contiguous rectangles, the basal units invariably heavily bordered with black, the more distal ones with less pronounced; or without, dark margins: in (*e*) fin ashen with a good deal of black, when laid back appearing wholly black. Caudal with membrane almost colorless, rays a little dusky; crossed by a dozen subvertical bars of deep orange, clear or tinged with brown; the proximal bar easily the best defined and most conspicuous, in the from of 2 proconcave arcs bordering the 2 lateral specialized scales on fin base; other bars less readily traceable as complete (increasingly so distally), becoming lost on membrane: in (*e*) whole fin is, additionally, heavily punctulated with black. The specialized caudal scales conspicuous, pale pinkish or yellowish, with a fan of diverging lines each bordered on either side at base with a streak of orange; hinder part of scale translucent. Pectoral chiefly whitish; about 10 cross bars formed by orange spots (often partly bordered and/or sprinkled with black) on the rays. Ventral whitish; with 6-8 orange or reddish annuli (sometimes, especially in the case of the proximal 3-4, margined with black) on each of the 2 main rays, often somewhat more intense on shorter ray.

TABLE VIII

Brachynectes fasciatus Scott, 1957. Meristic data, and dimensions, expressed as thousandths of standard length (*TLs*), of 7 specimens, (*a*)-(*g*), from Green's Beach, Devon, Tasmania, and 1 specimen, (*h*), from Cape Jervis, South Australia

Count or Dimension	Specimen (standard length, mm)							
	(*a*) 24.9	(*b*) 31.1	(*c*) 33.2	(*d*) 34.0	(*e*) 34.8	(*f*) 35.3	(*g*) 36.1	(*h*) 31.1
Dorsal	iii, x, 13	iii, x, 12	iii, x, 12	iii, x, 13	iii, x, 13	iii, x, 13	iii, x, 13	iii, x, 12
Anal	ii, 18	ii, 18	ii, 18	ii, 18	ii, 17	ii, 19	ii, 19	ii, 18
Pectoral (left/right)	13/13	11/13	13/14	13/12	13/13	13/12	13/13	13/13
Caudal (main rays)	12	13	13	13	12	13	13	13
L. lat. (anterior section, left/right; posterior section)	10/11; 20	11/12; 21	12/11; 19	11/11; 21	12/12; 20	12/14; 19	11/12; 19	13/12; 19
L. tr.	2/1/7	2/1/7	2/1/8	2/1/8	2/1/8	2/1/8	2/1/7	2/1/7
Scales between shoulder and caudal base	29	32	31	30	30	32	32	29
Total length	1,245	1,238	1,253	1,221	1,239	1,238	1,235	1,241
Length to—								
Origin of first dorsal	243	257	223	253	204	213	216	225
Termination of first dorsal (spine)	283	289	280	290	305	272	291	289
Origin of second dorsal	365	354	355	347	365	343	332	355
Termination of second dorsal (spine)	606	610	605	618	605	595	583	611
Origin of third dorsal	655	650	639	653	632	626	639	669
Termination of third dorsal (ray)	912	910	919	926	927	915	909	963
Origin of anal	490	505	506	475	486	514	454	502
Termination of anal (ray)	924	952	940	950	950	958	920	934
Origin of pectoral	247	277	271	262	256	256	277	286
Origin of ventral	205	228	209	206	200	197	198	193
Vent (middle)	474	482	476	449	457	493	415	482
Length of—								
First spine of first dorsal	120	96	151	129	125	136	111	116
First spine of second dorsal	116	95	108	97	116	119	111	82
First ray of third dorsal	123	127	120	119	112	112	125	130
Last ray of third dorsal	116	80	90	116	86	113	55	76
First spine of anal	64	63	66	59	52	65	66	47
Second spine of anal	88	90	92	88	75	79	80	66
First ray of anal	118	103	117	111	109	116	111	114
Last ray of anal	74	64	92	59	89	85	83	80
Pectoral (whole fin)	333	352	361	318	293	290	263	334
Longest (*nth*) ray of pectoral	313(7th)	296(7th)	283(8th)	276(8th)	273(8th)	280(8th)	249(8th)	315(7th)
First ventral ray	72	74	90	88	108	88	66	95
Second ventral ray	201	196	211	215	216	204	188	235
Third ventral ray	159	158	157	147	145	193	140	161
Head	325	322	332	335	316	290	306	322
Snout	88	80	89	88	78	85	76	77
Eye	82	95	87	90	83	79	84	93
Interorbital	52	48	57	53	57	57	66	63
Depth—								
Maximum	243	251	265	250	259	229	252	251
At opercular border	241	232	240	237	241	224	269	225
Before anal origin	239	248	244	224	247	227	247	225
Of caudal peduncle	100	96	116	103	103	99	108	96

Proportions as TLs.—Table VIII records, together with some fin and scale counts, a number of dimensions, expressed as thousandths of standard length, of all the 7 known Tasmanian specimens, arranged in ascending order of standard length, and, in the extreme right column, of the South Australian example from Cape Jervis noted as having been identified by T. D. Scott.

NOTES ON SURF FISHING CONTESTS HELD AT SWIMCART BEACH, DORSET IN APRIL 1965 AND MAY 1966.

In line with the recording of results of Californian Shark Derbies— see, *e.g.*, Herald, Schneebelli, Green & Innes (1960)—some data were given in an earlier contribution (1965: 64) on the catch at a fishing contest held at George Town, Dorset in January 1963. Some general observations on the Tasmanian Open Surf Angling Championship, sponsored by the St Helens Surf Angling Club, held at Swimcart Beach, near St Helens, Dorset, on 3rd, 4th April, 1965 and on 7th, 8th May 1966 are here given; the data being based on information kindly supplied by the Club's Secretary, Mr T. M. Brimfield (1965), Mr M. Franks (1966).

In the 1965 competition there were 259 entrants, and 159 fish were caught. The catch was noted as including about 30 flathead (probably *Platycephalus bassensis* Cuvier & Valenciennes, 1829); 75 salmon (*Arripis trutta esper* Whitley, 1950), heaviest 1 lb. 4 oz, 22 mullet (probably *Mugil cephalus* Linné, 1758); 1 gurnet (? *Trigla sp.*; ? *Ruboralga ergastulorum*), 2 lb 6 oz; 14 kelpies (*Pseudolabrus sp.*; the commonest form is *P. fucicola* (Richardson, 1840)); 16 skate, small, 1 shark (probably *Galeorhinus australis* (Macleay, 1881) or *Mustelus antarcticus* Günther, 1870), 19½ lb. In a letter dated 11th April 1965 Mr Brimfield observed, 'You would find that catches would vary considerably from year to year. Conditions were too calm for a good run of salmon. The Saturday after the contest two of our members caught almost as many cocky and blackback' [*i.e.*, young and adult of *Arripis trutta esper;* which many fishermen regard as distinct species] 'at Swimcart as the entire 259 anglers the week before.'

Fish caught in the 1966 contest numbered 224, as follows: 16 mullet, 8 oz-16 oz; 97 salmon, heaviest 4 lb 4 oz, 17 others over 2 lb (3 lb 1½ oz;3, 1; 2, 13½; 2, 13; 2, 13; 2, 11½; 2, 10; 2, 9½; 2, 9½; 2, 9; 2, 8½; 2, 8; 2, 7; 2, 6; 2, 5; 2, 4½; 2, 1½) 1 barracouta (*Leionura atun* (Euphrasen, 1791): the Commonwealth/State Fisheries has recently given official approval—reported in *Australian Fisheries Newsletter* (1966)—to a newly introduced vernacular name, snoek) 4 lb 13 oz; 10 rock cod (*Physiculus barbatus* (Günther, 1863)), 1 lb-2 lb; 88 kelp fish; 11 skate (including 4 specimens of *Raja whitleyi* Iredale, 1938 on which some observations are given earlier in this paper) 6 lb-11 lb; 1 shark (*Galeorhinus australis* (Macleay, 1881)).

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NOTES ON THE PLEISTOCENE DEPOSITS AT LEMONTHYME CREEK IN THE FORTH VALLEY

By

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(With three text figures)

ABSTRACT

The Pleistocene deposits at Lemonthyme Creek in the Forth Valley are further described. The pollen content of the glaciolacustrine sediments, the petrography of the tillite, and the compaction and cementation of the tillite are discussed.

INTRODUCTION

The following information is the result of further examination of the Pleistocene deposits in the Lemonthyme Creek Area of the Forth Valley. The deposits were originally described by Paterson (1965), and the present article records the results of an examination of pollen grains from the glaciolacustrine sediments, a petrographic description of the tillite, and a study of the compaction and cementation of the tillite.

GLACIAL DRIFT SEQUENCE (S.J.P.)

The drift sequence (Figures 1 and 2) consists of a basal tillite[4], interbedded tillite, varves, mudstones and siltstones, gravelly to bouldery till, and carbonaceous clays, silts and sands. These are overlain by periglacial solifluction material. The sequence is thought (Paterson, 1965) to contain the deposits of two glacial stages. The tillite, varves, mudstones and siltstones are thought to be the deposits of the first glacial stage, and three tillite layers indicating glacial advances have been recognised together with two varve-mudstone-siltstone layers indicating glacial retreats. The second glacial stage is thought to have commenced with the glacial advance that deposited the blanket of gravelly to bouldery till. It appears that this advance blocked the lower Lemonthyme Valley and created the lake in which the clays, silts and sands were deposited. The final filling of this channel was completed by periglacial solifluction. The probability of two glacial stages is inferred from the marked lithification of the tillite as compared with the overlying till.

POLLEN CONTENT OF THE CARBONACEOUS CLAYS, SILTS AND SANDS (S.L.D.)

Core from Drill Hole 5825 has been examined to ascertain the pollen content. Pollen grains in all the samples are sparse and poorly preserved, and a brief examination of all the samples suggests that there is little difference between them as far as pollen is concerned. The most abundant pollen is that of *Nothofagus*, which is represented by a number of types, including members of the *brassi* group (which no longer occur in Australia). There is also quite a variety of coniferous pollen grains, including *Microcachryidites antarcticus* Cookson and *Dacrydium mawsonii* (Cookson) Cookson, which are morphologically similar to the pollen of extant Tasmanian conifers. Other pollen grains occur only in small numbers; they apparently represent only a few different species, but this conclusion may be influenced by the paucity of pollen in the samples. Fern spores are present in all samples and, although the numbers are small, quite a wide variety of different types were found.

A rough count of 100 pollen grains from the top and bottom samples (76′ and 147′) confirmed the general opinion outlined above. Of the pollen grains whose structure could be made out, the sample at 76′ contained 65% *Nothofagus*, 26% conifers, 3% of proteaceous types and 6% of other kinds of pollen. The sample from 147′ contained 71% *Nothofagus*, 22% conifers, 3% proteaceous types and 4% of other kinds of pollen. Myrtaceous pollen was observed in the top sample (76′), pollen of Casuarinaceae at 92′ and 111′ and pollen of Ericales at 147′, but in each case only one or two pollen grains were found, so that these differences between levels cannot be regarded as significant. It is possible that the species of the more abundant pollen types and the spores may vary at different levels, but it was not possible to investigate this matter.

Many of the pollen grains could be either Tertiary or Quaternary age, and even a detailed examination of the material might fail to establish the status of some of these. Many of the *Nothofagus* pollen grains are considered to be Tertiary species. A random count of 50 *Nothofagus* pollen grains from the sample at 76′ was made, and this shows that at least half of the *Nothofagus* pollen could not belong to either of the extant Tasmanian species of the genus, and that at least four species are represented in the deposit. These include species of the *brassi* group, which is now confined to New Guinea and New Caledonia. This apparently means either that the pollen is derived, and that Tertiary material has been incorporated in these Pleistocene deposits, or that more than two species of *Nothofagus* (including members of the *brassi* group) existed in Tasmania during the Pleistocene period. Unfortunately, the nature of the material is such that it is impossible to decide between these alternatives. The pollen is poorly preserved, and thus it is possible that all or most of it is derived. There are no obvious differences between the

(1) Hydro-Electric Commission.
(2) School of Botany, University of Melbourne.
(3) School of Research Physics, Australian National University.

(4) Tillite—used in the rock sense as a consolidated and indurated till, but without the age connotation applied by Penck that the rock formed during glacial epochs anterior to the Pleistocene (Rice, 1955).

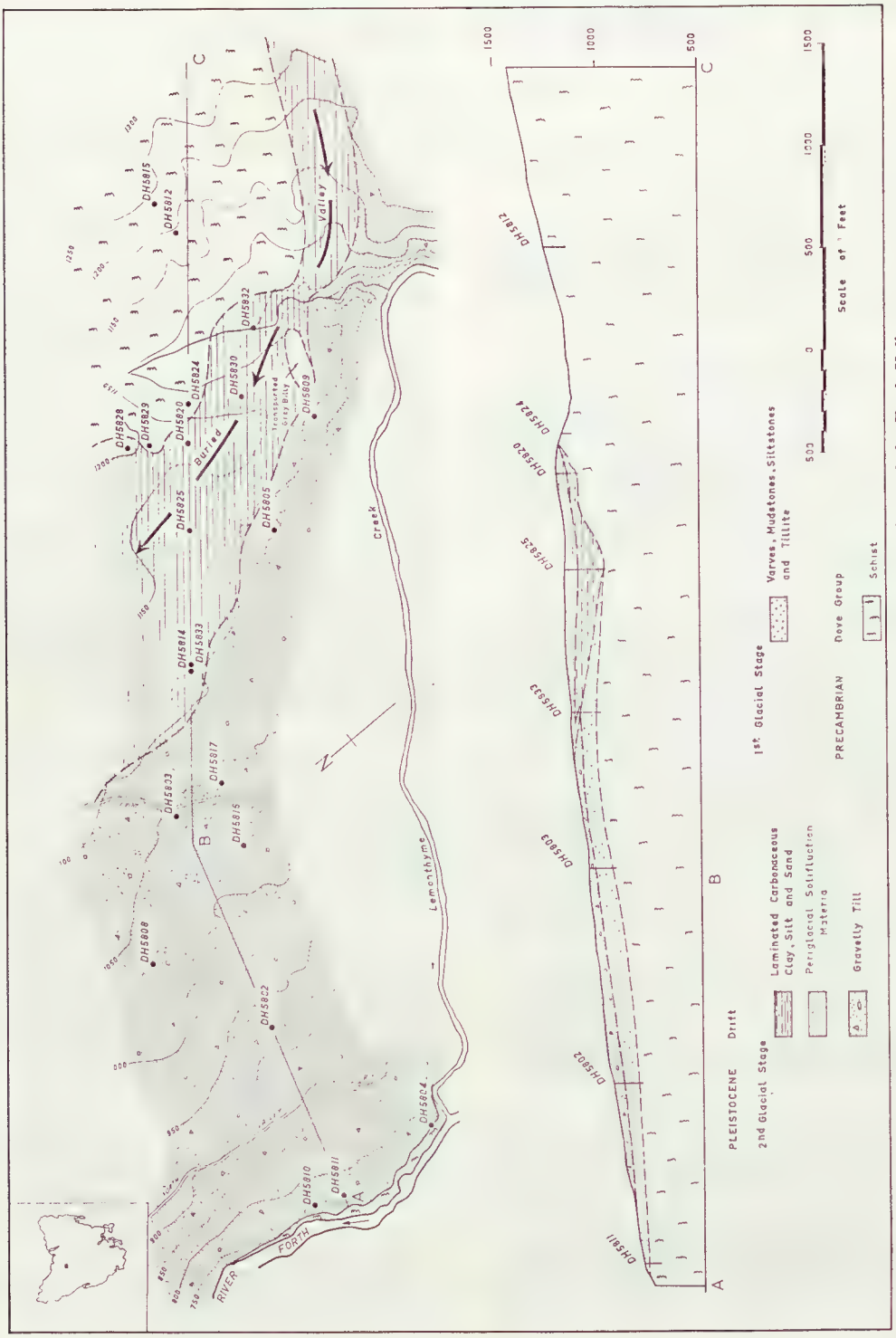

FIG. 1.—Pleistocene deposits in the Lemonthyme Creek Area of the Forth Valley.

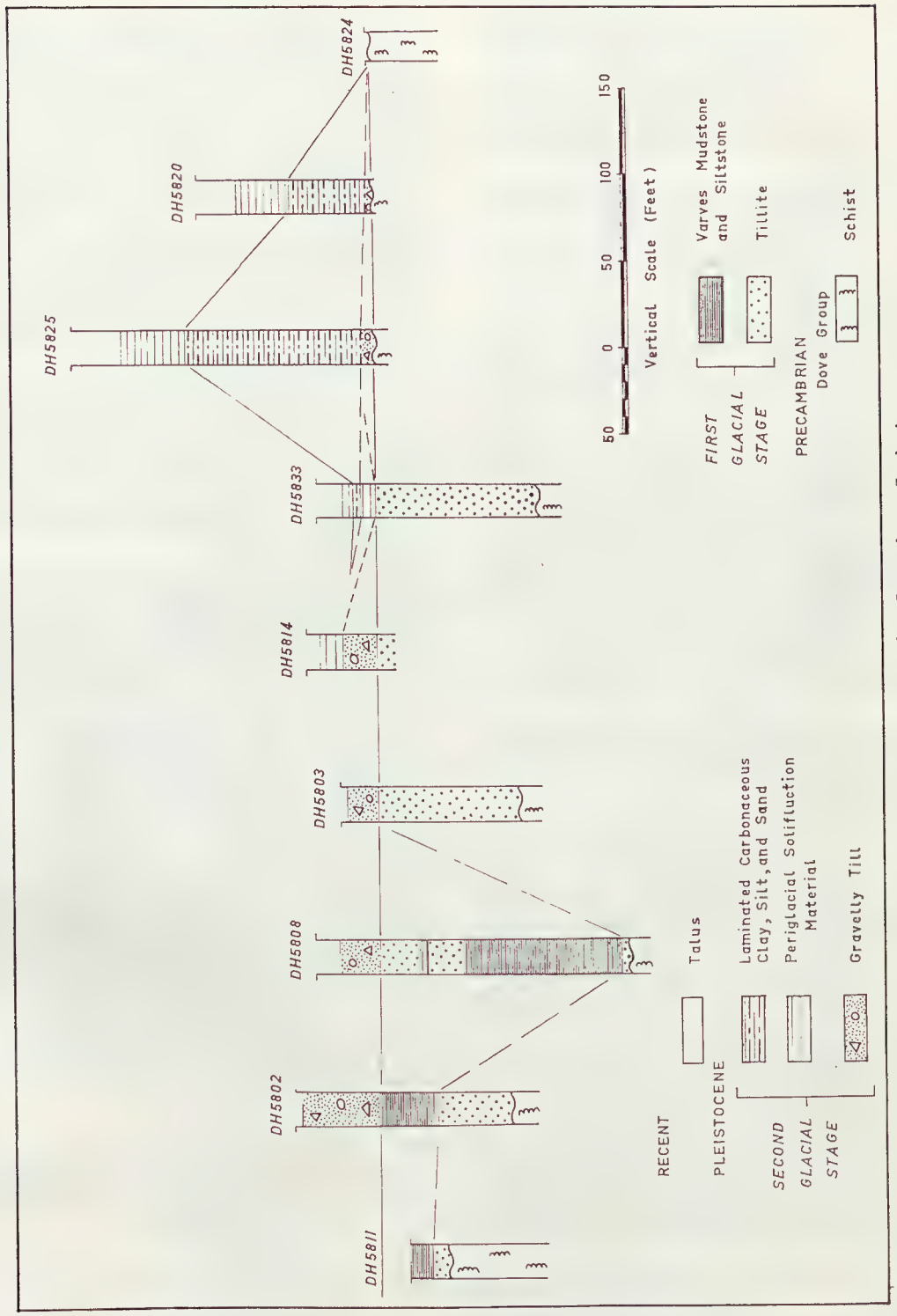

FIG. 2.—Stratigraphic Cross-section—Lemonthyme Creek Area.

preservation of the relevant *Nothofagus* pollen and the rest of the pollen in the sample, and thus it is unlikely that only this *Nothofagus* pollen is of derived origin. Some slight evidence against a derived origin for the bulk of the pollen is found in the fact that the pollen, although not abundant, is present in workable quantities, and that the same pollen flora appears to be represented through about 70′ of the deposit.

STRATIGRAPHIC POSITION OF THE CARBONACEOUS CLAYS, SILTS AND SANDS (S.J.P.)

In view of the uncertainty expressed above about the origin of some species of *Nothofagus* pollen grains, the following note is included to clarify the stratigraphic position of the sediments.

The sediments were deposited in a buried valley (Figure 1), a former channel of Lemonthyme Creek, which has been defined by drilling and seismic survey. Drill Hole 5833 on the western edge of the channel revealed the stratigraphic relationship, and indicated that the laminated carbonaceous clays, silts and sands overlie tillite. A maximum thickness of 110′ of these sediments were found in Drill Hole 5825, and the sediments have a dip of 3° and are overlain by 65′ of solifluction material. The presence of boulders, cobbles and pebbles of Jurassic dolerite and Tertiary basalt in the tillite clearly indicated that it is a Pleistocene tillite and that the sediments are thus part of the Pleistocene sequence. Before Drill Hole 5833 was drilled Spry (in Paterson, 1965) had concluded that the sediments in the buried valley were Pleistocene glaciolacustrine in origin from a petrographic study.

PETROGRAPHY OF SOME TILLITE SPECIMENS (G.A.J.)

The rock consists of angular to sub-rounded fragments ranging in size from 90 x 45 mm. to 2 x 1 mm. and a dark greenish brown matrix. Under the microscope the larger fragments are seen to consist of basalts, greywackes, siltstones, quartzites and quartz schists (the majority of the drill cores indicate a predominance of dolerite boulders, cobbles and pebbles (Paterson, 1965)). Basalt fragments predominate and they range from hypohaline types to completely holocrystalline types, though hypocrystalline are the most common. Larger fragments of basalt contain olivine, but in smaller fragments olivine is pseudomorphed by a brownish green material with a lamellar structure resembling iddingsite, though in places some of this material appears isotropic. Interstitial glass in the hypocrystalline rocks is partly or wholly altered to a similar material and this appears to have a very low birefringence. Apart from this alteration the rocks are absolutely fresh. A number of different grain-sizes and textures may be recognized among the basalt fragments some types being tachylytes with feldspar microlites, others fine granular basalts and others again medium to coarse grained ophitic rocks which might be called dolerites. All these rocks appear to be alkali basalts of Tertiary age and no Jurassic tholeiitic dolerites have been positively identified.

Tiny chips of the same rocks and minute fragments of quartz and pyroxene with or without cementing material form a kind of mortar between the larger fragments. These range in size from about 0.2 mm. to less than 0.001 mm.

One slide Drill Hole 5808-27′ shows definite cementing material binding the smaller chips of the mortar and forming a film around larger fragments. This cementing material closely resembles the brownish-green material found as an alteration product of glass and of olivine in the basalt fragments. It has a lamellar structure with tiny fibres arranged at right angles to the edge of the rock fragment (figure 3). It is possible that some of this material is a clay mineral of the montmorillonite group, possibly nontronite, though these minerals, like so-called iddingsite, have a medium birefringence, whereas much of the dark green material in these rocks appears to be nearly isotropic. It is possible that the cementing material is a mixture of clay minerals of the kaolinite and montmorillonite groups or even a chlorite, and the matter can probably be decided only by X-ray. It is of interest to note that in some rocks the alteration product of olivine, formerly identified as iddingsite, has in some cases proved to be an admixture of montmorillonite and iron oxides. In places a carbonate mineral also acts as a cement (Figure 3).

All stages of cementation may be studied in these rocks and there appears to be no relation between this and depth of burial.

Drill Holes 5808-56′ and 5814-50′ show only a trace of cementation, though interstitial glass in basalt fragments are almost completely altered. In both these rocks cohesion rather than cementation appears to be holding the fragments together. Both slides were difficult to grind and tended to break up.

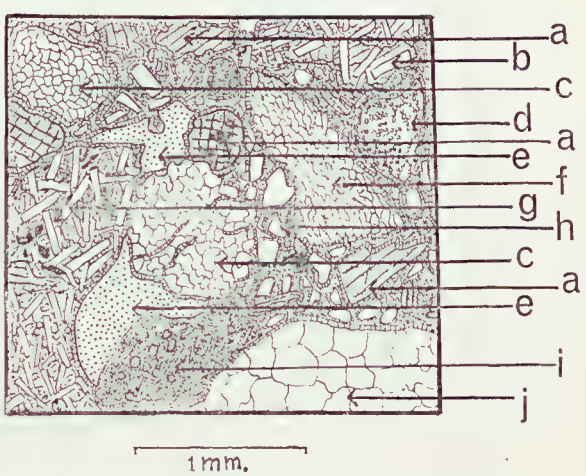

FIG. 3.—Tillite thin section—Drill Hole 5808-27′.

The clay film enveloping fragments has been exaggerated in width to show the fibrous structure.

a = pyroxene fragment
b = ophitic dolerite
c = quartzite
d = fine intergranular basalt
e = carbonate
f = quartz schist
g = coarse intergranular basalt
h = quartz chip surrounded by clay mineral
i = hypohaline basalt

Drill Hole 5803-88′ shows glass altering to a brown-green clay mineral and a little carbonate material and only incipient cementation.

Drill Hole 5817-20′ contains fragments of basalt showing complete alteration of glass, a film of brown-green clay around basalt fragments and cementation of smaller fragments in the immediate vicinity of basalt fragments, whereas no binding material or clay film was detected in the immediate vicinity of or around fragments of sedimentary or metamorphic rocks.

Cementation, therefore, appears to be very patchy. It begins with alteration within the basalt fragments, forms a film about them and about small quartz fragments close to them and finally migrates to and envelops the sedimentary and quartzose fragments elsewhere.

CEMENTATION AND COMPACTION (S.J.P.)

Most of the tillite core is well consolidated. and tests have revealed compressive strengths of up to 2568 lbs./sq. in. and tensile strengths averaging 353 lbs./sq. in. This indicates that in compressive strength the tillite corresponds to a weak sandstone, but its tensile strength is better than that found in most sandstones (Krynine and Judd, 1957).

Dr. J. C. van Moort of the Department of Geology, University of Tasmania has briefly studied the degree of cementation and compaction of the tillite by comparing samples of tillite with samples of till from Rowallan and Parangana Damsites and from Lemonthyme Creek. He found that the mineralogical composition of the fraction below 64 microns to be similar in each case. The phyllosilicates detected were illite, montmorillonite and chlorite. Microscopically no special cement was detected. He also studied the water content of the fraction below 64 microns. The results are given in Table I.

TABLE I.

Water Content

	H_2O—%	H_2O+%
Rowallan Till	0.3	13.5
Parangana Till	2.5	9.5
Lemonthyme Till	5.0	13.0
Lemonthyme Tillite .... (Drill Hole 5833 Depth 85′)	2.7	4.0

The low value of H_2O— for the Rowallan till is considered to merely indicate that the sample was well air dried before heating. The low value for H_2O+ for the tillite, however, is considered to be significant and to indicate that the tillite is much more dehydrated and compacted than the other specimens.

ACKNOWLEDGEMENTS

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Grateful acknowledgement is made to G. E. A. Hale and G. Rawlings of the Commission for helpful discussion, and the assistance of R. Preston in the preparation of figures is appreciated.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 101.

TASMANIAN TEMNOCEPHALIDEA

By

V. V. Hickman

(With 38 figures and 1 plate)

ABSTRACT

W. A. Haswell has described from Tasmania three species of *Temnocephala*, namely, *T. quadricornis*, *T. tasmanica* and *T. aurantiaca*. The descriptions are very brief. In the present paper they have been amplified. In addition three new species, *T. cita* and *T. fulva* from *Parastacoides tasmanicus* (Erichson) and *T. pygmaea* from *Astacopsis gouldi* (Clark), are described. Observations on the eggs, period of incubation, rate of growth and survival apart from the hosts are given. At ordinary temperatures the eggs of *T. cita* hatch in 67 days, *T. tasmanica* in 35-70 days, *T. quadricornis* in more than 196 days, *T. pygmaea* in 31-32 days, *T. aurantiaca* in more than 56 days and *T. fulva* in more than 60 days. The times taken to reach adult size by those species, which were hatched in the laboratory and reared apart from their hosts, are as follows: *T. tasmanica* 233 days, *T. pygmaea* 152 days and *T. aurantiaca* 117 days. In the case of *T. quadricornis* the rate of growth is such that adult size should be attained in about 190 days.

Most of the species, when removed from the host and kept under laboratory conditions, exhibit marked powers of survival. Thus specimens of *T. tasmanica* have lived for 707 days, *T. quadricornis* 76 days, *T. pygmaea* 59 days, *T. aurantiaca* 245 days. Young specimens hatched in the laboratory adapt themselves to the conditions more readily and often survive much longer than those removed from the host. Even in the absence of adequate aeration and food some species survive for lengthy periods. Thus, for example, an adult specimen of *T. tasmanica* placed in 3.0 ml. of water in a small tube, which was then firmly corked, lived for 100 days. *T. aurantiaca* treated in the same way lived for 70 days. During the period the animals decreased from adult size to that of a newly hatched specimen.

INTRODUCTION

Three species of *Temnocephala* have been recorded from Tasmania. They are *T. quadricornis Haswell* (1893), *T. tasmanica* Haswell (1900) and *T. aurantiaca* Haswell (1900). In a study of the family Temnocephalidae Pereira & Cuocolo (1941) placed the three species in a new genus, *Temnomonticellia*. Baer (1953) considers the establishment of the new genus not justified.

Haswell's descriptions of the three species are very brief and Baer (1931) expressed the opinion that a more thorough study of the three forms would undoubtedly justify uniting them in a single species. However, the present investigation shows that they are sufficiently distinct for them to be regarded as separate species.

Three new Tasmanian species are described, namely, *T. pygmaea* from the large fresh-water crayfish, *Astacopsis gouldi* (Clark), *T. cita* from the burrowing crayfish, *Parastacoides tasmanicus* (Erichson) and *T. fulva* also from *Parastacoides tasmanicus* (Erichson). A key distinguishing the Tasmanian *Temnocephala* from one another and from other Australian species is provided.

Some of the species have been maintained apart from their hosts for long periods. Observations on the incubation of the eggs, rate of growth of the young and survival under laboratory conditions are recorded.

A study of the literature on the Temnocephalidae reveals much difference of opinion concerning the function and naming of certain parts of the male and female reproductive systems. Fyfe (1942) calls the bulbous enlargement immediately preceding the base of the penis the granular vesicle and states that Haswell (1893) names it the coecal pouch. This, however, is not the case. Haswell gives the name coecal pouch or ejaculatory sac to the structure, which Fyfe designates the seminal vesicle, and the name cirrus bulb to the structure, which she calls the granular vesicle. The organ which Haswell and most other authorities call the seminal vesicle is termed by Fyfe the seminal duct. The organ which Haswell (1893) calls the coecal pouch or ejaculatory sac is termed an accessory bladder by Merton (1922) and prostate by Baer (1953). Table I indicates the equivalence of the terms used by the authors mentioned above.

Table I.

Haswell, 1893	*Merton*, 1922	*Fyfe*, 1942	*Baer*, 1953
Seminal vesicle	First seminal vesicle	Seminal duct	Seminal vesicle
Ejaculatory sac or coecal pouch	Accessory bladder of second seminal vesicle	Seminal vesicle	Prostate
Cirrus bulb	Second seminal vesicle	Granular vesicle	Ejaculatory vesicle

The terminology and functions of the bladder-like structure, usually called the *vesicula resorbiens*, have been fully discussed by Haswell (1924). It may be pointed out that the name is due to Merton (1913). Fyfe (1942) states incorrectly that it is due to Haswell. Incidentally the word *resorbiens*, which is in general use, should be *resorbens*, since it is derived from the Latin verb *resorbere*.

MATERIALS AND METHODS

Fresh-water crayfish collected in various parts of Tasmania and found to be carrying *Temnocephala* were brought back alive in water to the laboratory. The *Temnocephala* were then carefully removed from their hosts and placed in fresh water in glass dishes. They were fed on small particles of the internal organs of flies and other insects. In some cases chironomid larvae and small aquatic oligochaets were provided. The water in the dishes was renewed every two or three days but running water and special aeration were not required. The dishes containing the specimens were kept in a subdued light at ordinary room temperatures.

Eggs laid in the dishes were usually attached to the side or the bottom. Some, however, were not attached. These were placed on cotton wool submerged in water to prevent them from rolling about when the water was changed. Eggs taken from the hosts were removed together with the portion of integument to which they were attached. In this way handling of the eggs was facilitated and damage to them avoided.

Specimens of *Temnocephala* intended for sectioning were fixed in Apathy's alcoholic corrosive sublimate. The sections were stained in Ehrlich's haematoxylin and counterstained with eosin. Specimens for whole mounts were stained in alum carmine.

DESCRIPTION OF SPECIES

Order TEMNOCEPHALIDEA

Family TEMNOCEPHALIDAE.

Genus **TEMNOCEPHALA** E. Blanchard, 1849.

Key to Australian species of *Temnocephala*.

1. Six tentacles present 2
   With less than six tentacles 3
2. Opaque, white and without pigment *T. comes* Haswell.
   Brown in colour ..... *T. simulator* Haswell.
3. With five tentacles 4
   With four tentacles and a flat median lobe 10
4. With a pair of posterior glandular organs *T. chaeropsis* Hett.
   Without such organs 5
5. Eyes absent ..... *T. caeca* Haswell.
   Eyes present 6
6. Pigmented with dark brown *T. fasciata* Haswell.
   Grey or white without pigment 7
7. Cilia behind tentacles ..... *T. minor* Haswell.
   No cilia behind tentacles 8
8. Testes lobed ..... *T. dendyi* Haswell.
   Testes not lobed 9
9. Front testes smaller than hind testes *T. engaei* Haswell.
   Front testes larger than hind testes *T. cita* sp. n.
10. Eyes absent ..... *T. tasmanica* Haswell.
    Eyes present 11
11. Dark brown ..... *T. quadricornis* Haswell.
    Not so coloured 12
12. White without pigment ..... *T. pygmaea* sp. n.
    Yellow or brownish yellow 13
13. Four pairs of intestinal septa *T. aurantiaca* Haswell.
    Seven pairs of intestinal septa ..... *T. fulva* sp. n.

Temnocephala cita sp. n.

(Text-figs. 1-7, Pl. I, fig. 1.)

General features. The animal (Text-fig. 1) is somewhat elongate. The largest specimens when contracted are about 1.26 mm. long and 0.69 mm. wide. When fully extended they measure about 2.86 mm. long and 0.38 mm. wide. The dorsal surface is convex and the ventral surface flat or slightly convex. There are no marginal flanges and the fully extended animal is almost cylindrical. Apart from the eyes there is no pigmentation, the body being white and translucent, with the intestine clearly visible through the integument. Five subequal tentacles are present, the outer one on each side being slightly shorter than the others. The eyes are situated a short distance behind the base of the median tentacle. The excretory pores open one on each side in a plane slightly behind the eyes. The mouth is a slit-like aperture in the normal position on the ventral surface about 370μ from the base of the tentacles. The sucker is 300μ in diameter and extends slightly beyond the posterior end of the body. The genital aperture is slightly in front of the sucker.

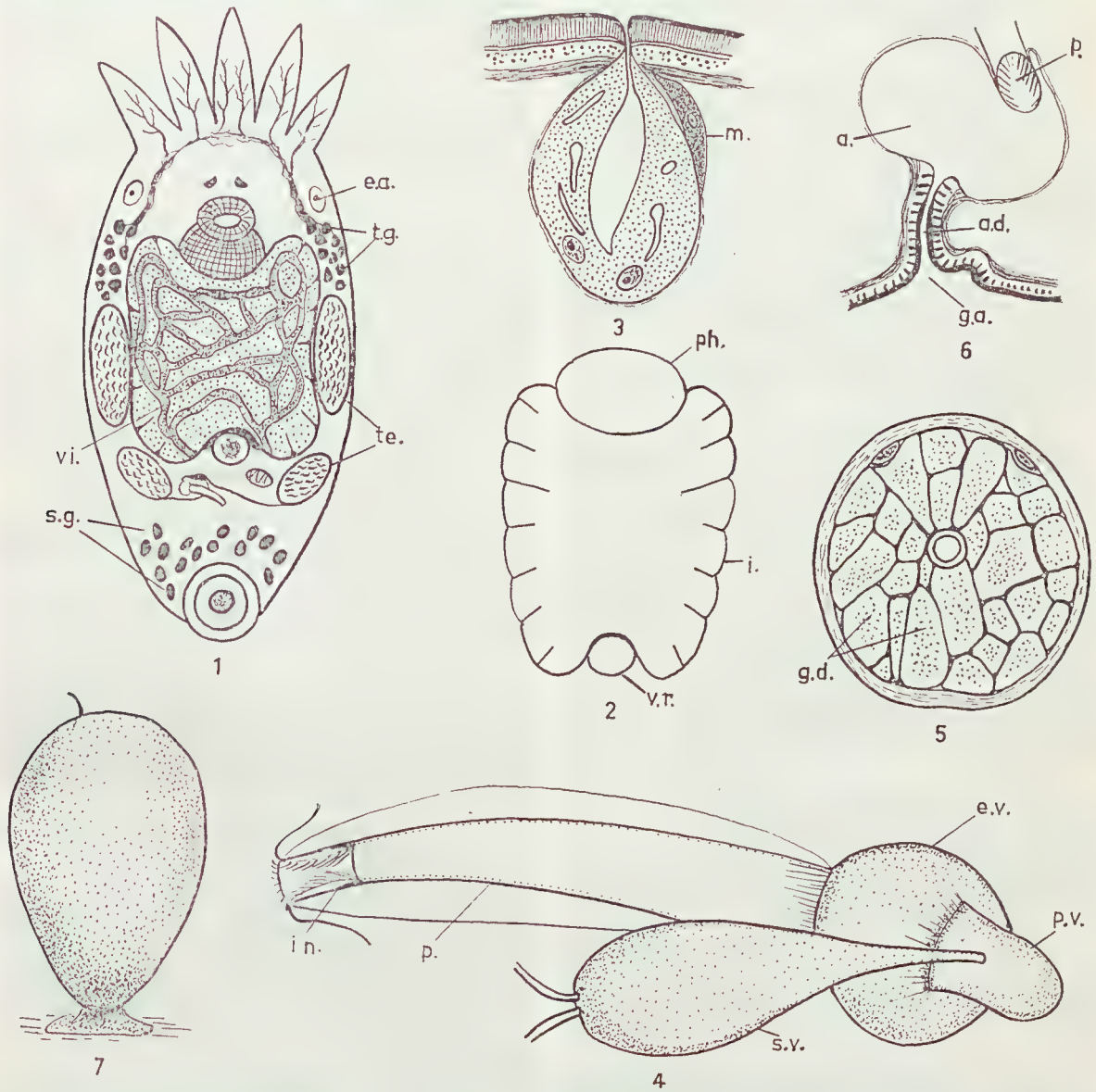
Body-wall and Integumentary Glands. The cuticle is smooth and perforated by numerous small pores. In section the epidermis has the usual striated appearance. The nuclei are few and widely scattered. They are generally oval in shape and measure about 15μ x 12μ. Their form, however, depends on the degree of contraction or extension of the animal. In some cases they are very flat. A thin basement membrane is present below the epidermis. No cilia occur on any part of the integument.

The dermal muscular sheath is composed of the usual transverse, diagonal and longitudinal fibres. On the ventral side the longitudinal fibres are more strongly developed than elsewhere. In front of the mouth are a number of transverse muscles, which lie internal to the layer of ventral longitudinal fibres. Numerous dorso-ventral muscles occur throughout the body.

The tentacular or rhabdite glands form a group lying between the excretory vesicle and the anterior testis on each side of the body. The glands are mainly pyriform in shape. They do not extend in front of the excretory vesicles but their fine thread-like ducts pass forward and give off branches to the tentacles. The median tentacle receives branches from the glands on each side of the body. Both the glands and their ducts stain deeply with haematoxylin. The rhabdites measure about 3μ in length and the cell nucleus 10μ in diameter. The

sucker glands are situated behind the posterior testes and also in front of the sucker. They are irregular in shape and their nuclei about 12μ in diameter.

Digestive System. The mouth leads into a short prepharynx or pharyngeal pouch. The pharynx has the form of a pharynx bulbosus and is about 190μ in diameter. It is provided with a large number of pharyngeal glands, which are situated among the radial muscles and are more numerous dorsally than ventrally. The posterior sphincter muscles are more strongly developed than are the anterior ones. Between the pharynx and the intestine is a short oesophagus, but oesophageal glands appear to be absent. The intestine is a somewhat rectangular sac which, except in the contracted condition, is longer than wide. It has a number of slight constrictions. In front it projects on each side of the pharynx. Posteriorly it is concave round the vesicula resorbens. The lumen of the intestine is partly divided by seven pairs of lateral septa (Text-fig. 2).



Temnocephala cita sp.n.

Fig. 1.—General view of external and internal features.
Fig. 2.—Outline of digestive canal.
Fig. 3.—Section of excretory bladder.
Fig. 4.—Male reproductive organs.
Fig. 5.—Transverse section of ejaculatory vesicle.
Fig. 6.—Sagittal section of atrium and atrial duct.
Fig. 7.—Egg viewed from the side.

Excretory Bladder. The excretory apertures are situated one on each side of the dorsal surface. They lie in a transverse plane slightly behind the eyes and are about 45μ from the margin. The excretory bladder is pyriform, 75μ long and 45μ wide. It has a very thick wall, which appears finely granular and contains a number of small canals and vacuoles (Text-fig. 3). At the base of the vesicle are two nuclei. A thin muscular investment surrounds the bladder, but the thick fibrous layer seen in some other species is absent. A long spindle-shaped myoblast is closely applied to the anterior surface of the bladder and extends up to the aperture.

Nervous System. The brain and main nerve cords are similar to those in other species of *Temnocephala*. The width of the brain is about 150μ and it has the form of a transverse band of fibrous material. At each side it is curved slightly downward and backward. Anteriorly it gives off a pair of stout nerves which pass forward forming branches which enter the tentacles. From the sides of the brain the usual three pairs of longitudinal cords arise and pass posteriorly. Associated with each side of the brain are numerous ganglion cells with nuclei about 12μ in diameter. Immediately above the front of the brain are the two eyes. Each has the form of a pigmented cup, which is poised obliquely. In the mouth of the cup is a clear refractive body. The eyes are about 24μ in diameter and 30μ apart.

In front of the brain are two pairs of large cells, one pair above the other. The upper pair are about 33μ in diameter. Their cytoplasm is vacuolated and their nuclei measure 15μ in diameter. The lower pair are of about the same size but their cytoplasm is finely granular and their nuclei 18μ in diameter. These cells do not seem to form part of the nervous system but are always closely associated with the brain and are therefore mentioned in this section. Haswell (1893) figures similar cells in *T. fasciata* and refers to them as "problematical cells". They may be paranephrocytes concerned with excretion, but as Fyfe (1942) points out paranephrocytes are wandering cells. The paired cells in front of the brain in *Temnocephala* appear constant in position and to occur in most species.

Reproductive System. In the male system there are two pairs of testes, an anterior pair and a posterior pair. The anterior testes are oval and elongate being about 493μ long and 82μ wide. They are situated one on each side of the intestine. The posterior testes are also oval but much shorter than the anterior pair. They measure 301μ long and 164μ wide. They are situated somewhat obliquely behind the lateral angles of the intestine. A short duct passes from the posterior end of each anterior testis to the ventral side of the neighbouring posterior testis. The vasa deferentia arise ventrally from the posterior testes and run transversely to enter the base of the seminal vesicle.

The seminal vesicle (Text-fig. 4) lies more or less obliquely in front of the penis. When distended with spermatozoa it is somewhat pyriform. It is about 96μ-150μ in length and 42μ-45μ in diameter at its widest part. Its narrow distal end (seminal duct) enters the anterior side of the prostate vesicle.

The prostate vesicle is a bladder-like structure projecting from the anterior side of the ejaculatory vesicle. It has a muscular wall and a thick finely granular protoplasmic lining which contains few nuclei and no cell boundaries. Its lumen is continuous with that of the ejaculatory duct.

The ejaculatory vesicle is somewhat spherical and 51μ-66μ in diameter. The ducts of the granule glands enter the front of the vesicle below the junction with the prostate vesicle. They fill the lumen surrounding the ejaculatory duct and extend into the penis. In a transverse section of the vesicle the ducts appear polygonal in form, probably due to mutual pressure (Text-fig. 5). The seminal, prostate and ejaculatory vesicles have a continuous muscular investment consisting of an outer layer of circular fibres and an inner layer of longitudinal fibres.

The penis (Text-fig. 4), surrounded by the cirrus sac, lies to the left of the median plane in a more or less transverse position. It is slightly curved and slopes downward towards the atrium. It has the usual form of a chitinous tube surrounded by two muscular layers continuous with those surrounding the ejaculatory vesicle. Its length is 144μ-180μ, its diameter being 36μ-42μ at the base and 15μ-18μ at the apex. The introvert forms about one sixth of the total length of the penis. In the inverted state the inner wall of the introvert is lined with numerous spines, which vary in length from 7μ-27μ, the longer spines being towards the base and the shorter ones towards the apex.

Granule glands occur on each side of the intestine and also surround the greater part of the seminal vesicle, but their ducts could be found only where they entered the ejaculatory vesicle.

The female part of the reproductive system consists of the usual organs, namely, the germarium, vesicula resorbens, receptacula seminis, ootype, uterus and vitellarium.

The germarium is oval in shape and about 90μ long and 69μ wide. It is situated to the right of the median plane and slightly behind the vesicula resorbens. The ova have the characteristic wedge shape. The germiduct is very short and the germarium opens almost directly into the right side of the ootype.

When not compressed the vesicula resorbens is more or less spherical and 45μ-75μ in diameter. In some specimens the lining of the vesicle is thick and finely granular with a number of nuclei. In other specimens it may be thin and without nuclei. An open genito-intestinal canal was not present in any of the specimens examined. In one, however, the anterior wall of the vesicle formed a narrow extension into the epithelium of the intestine, as if a canal were in process of formation. Posteriorly a short duct from the vesicle becomes continuous with the ootype.

There are four receptacula seminis. They surround the ootype and enter into it slightly anterior to the entrance of the germiduct. Each is finger-like in shape and about 39μ long and 12μ in diameter.

The ootype has very thick muscular walls and small lumen. Behind the entrance of the germiduct it bends ventrally and expands to form the uterus. The latter is a much larger chamber, which in the non-gravid condition has folded walls. Opening into it and also into the ootype are a number of unicellular glands. A narrow vagina surrounded by strong circular and radial muscles leads from the lower part of the uterus to the right side of the atrium, into which it opens.

The vitellarium consists of a number of glands situated above and below the intestine. They form a somewhat reticulate pattern (Text-fig. 1). Posteriorly they give rise to two vitelline ducts, which open, one on each side, into the ootype.

The atrium varies considerably in appearance in different specimens. In the gravid condition or immediately after egg-laying it is a large oval chamber with smooth walls. At other times it is much smaller and has folded walls. A number of pyriform unicellular glands open into it. The atrial duct arises from the middle of the ventral suface of the atrium and leads to the genital aperture. It is about 27μ long, curved slightly forward and surrounded by strong sphincter muscles (Text-fig. 6).

Host and Locality. *Temnocephala cita* was taken from specimens of the burrowing land-crayfish, *Parastacoides tasmanicus* (Erichson), found living in tunnels in damp soil near Lake Pedder, Western Tasmania, 25th February, 1966. The species occurred mainly on the pleopods and under surface of the abdomen. A few were found in the gill chambers.

Eggs and Incubation. The eggs are pale yellow in colour and pyriform in shape (Text-fig. 7). They measure 0.343-0.457 mm. long and 0.228-0.286 mm. wide. They are generally attached by the narrow end to the anterior surface of the pleopods. (Plate I, fig. 1). At the wider distal end the chorion is produced into a short slender projection, A few eggs were found in the gill chambers of the crayfish. Unlike the eggs on the pleopods they were attached along one side and not by the narrow end. This difference in the mode of attachment suggested that the eggs might belong to another species. However, when the eggs were hatched in the laboratory, the young were found to be no different from those hatched from eggs on the pleopods. No doubt the narrow space in the gill-chamber compelled the animal to attach the eggs in the manner described.

An egg laid in the laboratory on 2nd March, 1966, was attached by its narrow end to the side of a glass dish containing water in which a number of adults were being kept. It hatched on 8th May, 1966, after a period of 67 days, the average temperature of the water during the period being 16°C. Fifteen eggs were removed from specimens of the crayfish and hatched in the laboratory. The longest time required for any one of the eggs to hatch was 53 days.

The newly hatched young are white and translucent. When contracted they are about 0.514 mm. long and 0.343 mm. wide, but they are able to extend to a length of about 1.37 mm.

Survival apart from the host. *T. cita* proved more difficult to maintain under laboratory conditions than any other of the Tasmanian species. Newly hatched young ones did not survive longer than 13 days and the rate of growth was therefore not studied. Most of the adults removed from their host lived for less than a month. The crayfish, *Parastacoides tasmanicus*, was found to carry numerous Rotifers, Vorticellids and Macrostomids. It is probable that some or all of these formed the natural food of *T. cita* and that such food was necessary for survival.

Temnocephala tasmanica Haswell

(Text-figs. 8-13, Pl. I, fig. 2)

General Features. In the contracted condition the largest specimens are about 2.85 mm. long and 1.30 mm. wide. When fully extended they measure about 5.1 mm. in length and 0.86 mm. in width. There are four long tentacles and a short median truncate lobe (Text-fig. 8). No eyes are present. Haswell (1900) gives a drawing of the anterior end of the body, which shows a pair of eyes. This is apparently an error and in contradiction to the text, in which he states "there are no eyes". The colour of the body is usually pale cream or white. In some specimens, however, the dorsal surface is tinged with orange in front of and behind the region of the intestine. Haswell (1900) states "the integument is devoid of pigment". The body is convex above and flat below. The excretory apertures are situated, one on each side of the dorsal surface, in a transverse plane slightly behind the front of the pharynx, and about 240μ from the lateral margins. The mouth is an oval aperture in the usual position on the ventral surface and about 490μ from the front. The genital aperture lies about 330μ in front of the ventral sucker. The diameter of the sucker is 590μ. The posterior end of the body extends slightly beyond the sucker.

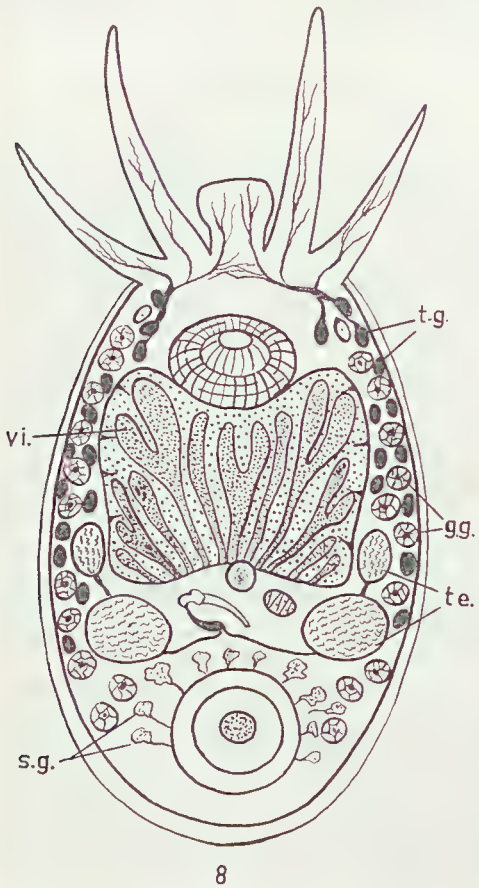
Body-wall and Integumentary Glands. The integument consists of the usual layers, namely cuticle epidermis and basement membrane. The cuticle is about 3μ in thickness and is perforated by a large number of small pores. Its surface especially on the dorsal side, has a rough appearance due to the presence of numerous minute papillae. The epidermis is about 6μ in thickness and has the usual striated structure with widely scattered nuclei. The basement membrane varies in thickness, in some places being extremely thin, in others almost as thick as the cuticle.

The dermal muscular sheath consists of an outer layer of circular or transverse muscles, an inner layer of longitudinal muscles and an intermediate layer of diagonal fibres. The layer of circular muscles is about 6μ in thickness, that of the longitudinal muscles 15μ in thickness. In front of the mouth and immediately internal to the ventral longitudinal muscles is a layer of transverse fibres, which extends round the lateral angle on each side and for a short distance below the layer of dorsal longitudinal muscles. Numerous dorso-ventral fibres pass through the parenchyma in all parts of the body.

The tentacular or rhabdite glands form a lateral series situated on each side of the intestine. They extend forward to slightly in front of the excretory bladder and backward to the posterior testes. Most of them are dorsal to the granule glands (described under the reproductive system). The sucker glands

are in the posterior part of the body in front of and on each side of the sucker. Their ducts converge towards the stalk.

Digestive System. The mouth leads into a short prepharynx or pharyngeal pouch. The pharynx has the form of a pharynx bulbosus. It is relatively large measuring 500μ long and 570μ wide. The posterior sphincter muscles are very strongly developed. A number of unicellular pharyngeal glands lie in the spaces between the radial muscles. Between the pharynx and the intestine is a short oesophagus with a folded inner wall. It is sur-



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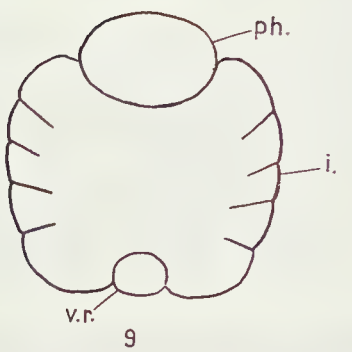

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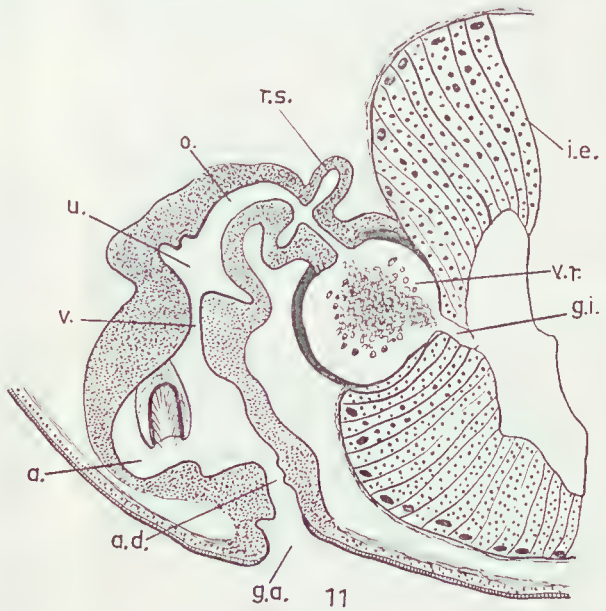

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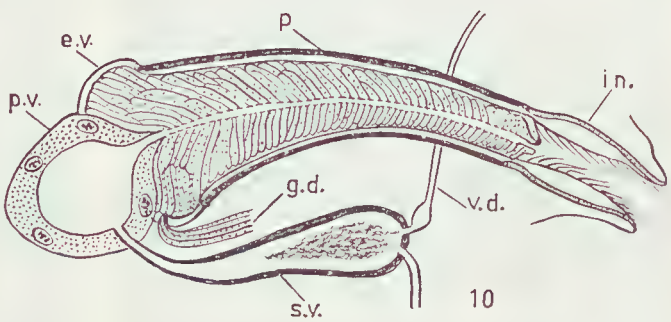

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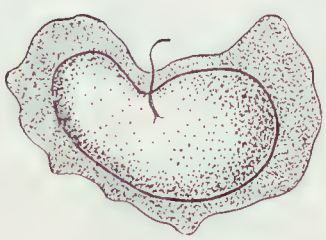

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Temnocephala tasmanica Haswell.

Fig. 8.—General view of external and internal features.
Fig. 9.—Outline of digestive canal.
Fig. 10.—Longitudinal section of male reproductive organs.
Fig. 11.—Longitudinal section of female reproductive organs.
Fig. 12.—Egg viewed from above.

rounded by strong sphincter muscles and numerous unicellular pyriform glands. The intestine has the usual form of a more or less rectangular sac, which is shorter than wide. The anterior wall projects forward slightly on each side of and below the pharynx. The posterior wall forms a concavity round the vesicula resorbens. The lumen of the intestine is partially divided by four septa on each side (Text-fig. 9). Haswell states that the intestine is devoid of constrictions and septa. In all the specimens I have examined septa are present, but external constrictions slight or not evident.

Excretory Bladder. As mentioned above the excretory apertures are in the usual position and about 140μ from the margin. The excretory bladder is somewhat pyriform, 610μ long and 410μ wide. On the postero-lateral side it is coiled on itself. The loop narrows distally and becomes continuous with the excretory duct. Near the base of the bladder the duct divides to form two branches, one of which curves dorsally and follows the course of the longitudinal dorso-lateral nerve, the other passes ventrally and follows the ventral longitudinal nerve. Smaller branches pass anteriorly from near the junction of the two main ducts.

Nervous System. The brain and nervous system conform to the usual arrangement in *Temnocephala*. The brain is situated in front of the pharynx and is about 150μ in width. It curves slightly downward on each side. Two stout nerves are given off from the front of the brain, pass forward and divide to form branches which enter the tentacles and median lobe. The usual dorsal, dorso-lateral and ventral longitudinal nerves arise from each side of the brain.

As in the previous species there are two pairs of large cells in front of the brain. They lie between the two anterior nerves. The lower pair of cells are fused together, their cytoplasm forming a finely granular syncytium. The total diameter is about 180μ. The two nuclei are oval and measure 30μ x 27μ. The upper pair of cells are separate and slightly smaller, each being 81μ in diameter. The cytoplasm appears somewhat fibrous forming radial strands round the nucleus, which measures 21μ x 18μ.

Reproductive System. In the male system there are two pairs of testes, an anterior and a posterior pair. The anterior pair lie one on each side of the posterior quarter of the intestine. They are ovoid in shape and measure about 360μ long and 290μ wide. The posterior testes are situated one on each side behind the lateral angles of the intestine. They are also ovoid, but larger than the anterior pair, being 490μ long and 360μ wide. A short duct passes from the posterior end of the anterior testis to the anterior side of the neighbouring posterior testis.

The vasa deferentia arise from the inner ends of the posterior testes. That from the right testis passes in front of the atrium to the base of the seminal vesicle, which is situated to the left of the median plane. The vas deferens from the left testis is shorter and wider than that from the right testis and passes directly to the base of the seminal vesicle. The two vasa deferentia enter the seminal vesicle independently.

The seminal vesicle is elongate and pyriform. When filled with spermatozoa it is about 210μ long and 70μ wide. It lies more or less transversely below the penis. Its wall has an outer layer of circular muscles surrounding a layer of longitudinal muscles. The lumen is lined with a thin layer of protoplasm. The seminal duct formed by the narrow distal end of the vesicle enters the prostate vesicle ventrally.

The prostate vesicle is a rounded or oval sac, about 81μ long and 90μ wide. It has muscular walls and a thick finely granular protoplasmic lining containing a few nuclei but no cell boundaries. It forms a wide junction with the ejaculatory vesicle. Its lumen is continuous with that of the ejaculatory duct. Haswell (1900) gives a figure of the male reproductive system but omits the prostate vesicle and does not mention it in his very brief description.

The ejaculatory vesicle is about 110μ in diameter, but shorter than the prostate vesicle. Near its junction with the latter on the postero-ventral side it is entered by the fine ducts of the granule glands. On passing through the wall of the vesicle the ducts form numerous branches, which surround the ejaculatory duct. They extend into the penis almost as far as the introvert and open into the ejaculatory duct for most of its length (Text-fig. 10).

The penis is situated transversely on the left of the median plane and curves downward towards the atrium. It has the usual form and is about 300μ long. At the base it is 100μ wide, but tapers to 45μ wide at the apex. The introvert forms about three tenths of the length of the penis. In the inverted state the wall of the introvert is lined with sharp spines, which vary in length from 12μ to 60μ the longer spines being near the base and the shorter ones near the apex.

The granule glands are large and conspicuous. Most of them lie at the sides of the body below the rhabdite glands. They are unicellular, more or less rounded and lobed. They measure up to 90μ in diameter. Their cytoplasm has the appearance of a reticulation formed by minute granules. The nucleus is central and about 24μ in diameter. The glands stain faintly with haematoxylin. Some granule glands lie near the testes, vasa deferentia and seminal vesicle. Their ducts enter the ejaculatory vesicle in the position already described.

The female reproductive system (Text-fig. 11) consists of the germarium, vesicula resorbens, receptacula seminis, ootype, uterus, vitellarium and associated glands.

The germarium lies on the right side of the median plane close behind the intestine. It is ovoid in shape and measures 165μ long and 105μ wide. From its inner end arises a very short germiduct, which opens into the ootype. The advanced ova in the germarium have the characteristic wedge shape. The more immature ova at the end remote from the germiduct are small and rounded.

The vesicula resorbens is a rounded bladder incorporated in the posterior wall of the intestine. It may be spherical, ovoid or pyriform in shape and may vary in diameter from 90μ to 126μ. Its outer wall has a thin muscular investment. Its lumen usually has a thick lining of granular protoplasm with a few nuclei but no cell boundaries. In some cases no nuclei are present. In sections of three

specimens the anterior end of the vesicle had formed a temporary genito-intestinal canal leading into the lumen of the intestine. Haswell (1924) records a similar feature in specimens of *T. tasmanica*, which he examined. Posteriorly the vesicula resorbens gives rise to a short duct, which becomes continuous with the ootype.

There are four receptacula seminis. They have the form of narrow diverticula about 45μ long and 18μ wide. They are arranged more or less symmetrically round the ootype and open into it a short distance behind the vesicula resorbens and anterior to the entrance of the germiduct.

The ootype passes posteriorly for a short distance and then curves downward enlarging to form the uterus. In the non-gravid condition the uterus has strongly folded walls. Ventrally it forms a narrow vagina opening into the right side of the atrium. The ootype and uterus have thick muscular walls and are surrounded by a number of pyriform unicellular glands, which stain darkly with haematoxylin.

The vitellarium lies above and below the intestine. It has the form of a number of thick elongate lobes which are slightly branched and lie more or less longitudinally. Posteriorly the vitellarium forms a pair of vitelline ducts, which open, one on each side, into the ootype near the openings of the receptacula seminis.

The atrium is a large transverse chamber with strongly folded muscular walls. It lies slightly behind the genital aperture and the atrial duct slopes downwards and forwards. A number of unicellular cement glands surround the atrium and also the atrial duct. The genital aperture is a short transverse slit-like opening situated close in front of the anterior margin of the sucker.

Hosts and Localities. This species occurs on the small freshwater crayfish, *Astacopsis franklinii* (Gray), found in creeks flowing down the slopes of Mount Wellington, especially at the Cascades and Lenah Valley. Haswell (1900) states that the specimens examined by him were "found in the branchial cavities of *Astacopsis tasmanicus* in small streams near Hobart". There is little doubt that the two crayfishes belong to the one species.

Temnocephala tasmanica usually occurs on the great chelae and mouthparts of the host, but if large numbers are present they may also occur on the carapace, legs and abdomen. A crayfish taken at the Cascades on 9th March, 1966, carried 150 specimens of the temnocephalid distributed over most of the body.

The species was also found on specimens of the large fresh-water crayfish, *Astacopsis gouldi*, (Clark), taken in the river Don at Sheffield in northern Tasmania, 23rd December, 1964.

Eggs and Incubation. The eggs (Text-fig. 12 and Pl. I, fig. 2) are distinctly reniform and narrower at one end than at the other. They measure about 510μ long and 290μ wide, the capsule is brownish and transparent. On the upper side, and nearer to one end than the other, the capsule is produced into a short narrow projection with a curved or twisted tip. The eggs are always deposited in the gill chamber of the crayfish. They may be fastened to the thoracic wall, the gills or the inner wall of the branchiostegite. The eggs are not massed together but attached singly. The whole under-surface of the capsule is firmly cemented to the place of attachment. The cementing material is often voluminous and in some cases almost envelops the capsule.

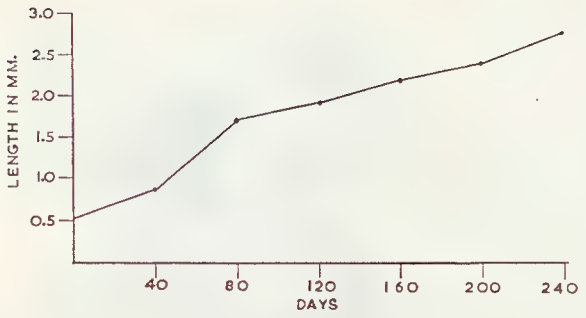
Specimens of *T. tasmanica* removed from the host and kept in water in glass dishes sometimes deposited eggs in the dishes. The eggs were either attached to the side or free on the bottom of the dish. Five eggs (A-E) were kept until they hatched. The period of incubation (Table 2) varied considerably, being partly dependent on temperature conditions. On hatching the upper surface of the egg-capsule fractures allowing the young one to escape.

Rate of growth. An egg removed from the gill chamber of *Astacopsis franklinii* hatched on 12 February, 1964. The newly hatched young one in the contracted state measured 0.57 mm. long and 0.40 mm. wide. At the end of 233 days it measured, when contracted, 2.85 mm. long and 1.30 mm. wide. The average temperature of the water during the period was 14.9°C. The rate of growth is shown in the graph (Text-fig. 13).

Survival apart from the host. T. tasmanica is readily maintained under laboratory conditions. Two specimens removed from the crayfish, *Asta-*

TABLE 2.

Egg	*Date laid.*	*Date hatched.*	*Period of incubation in days.*	*Average temperature of the water in degrees C.*
A	24 September, 1964	3 December, 1964	70	16.4
B	24 December, 1964	28 January, 1965	35	18.0
C	24 December, 1964	6 February, 1965	44	18.0
D	30 January, 1965	22 March, 1965	51	18.7
E	27 March, 1965	27 May, 1965	61	16.0



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Temnocephala tasmanica Haswell.
Fig. 13.—Graph showing growth of a specimen reared apart from its host from date of hatching, 12th February, 1964, to 2nd October, 1964, that is for 233 days.

copsis franklinii, were placed in water in a glass dish on 23rd October, 1964. The water in the dish was changed occasionally, but no special aeration was provided. The specimens were fed mainly with small particles from the internal organs of flies, especially from the intestine, fat body and Malpighian tubules. The two specimens are still alive at the present time, 30th September, 1966, after being maintained apart from the host for a period of 707 days.

T. tasmanica is able to survive for considerable periods without food and with very little air. An adult specimen was placed in 3.0 ml. of water in a specimen tube measuring 5.0 cm. x 1.2 cm. and the tube then firmly corked. No food was given and the cork was not removed. The specimen lived from 30th November, 1964, until 10th April, 1965, a period of 100 days. During this time it decreased in length from about 2.5 mm. to 0.46 mm.

Temnocephala quadricornis Haswell.

(Text-figs. 14-19)

General Features. In the contracted state the largest specimens measure about 9.0 mm. long and 6.0 mm. wide. The species is the largest member of the genus occurring in Tasmania. The colour of the dorsal surface is dark brown mottled with yellowish brown. A pair of yellowish spots marks the position of the excretory apertures and there is usually a transverse patch of yellow above the region of the intestine. The ventral surface is light brown and the lateral flange almost colourless. There are four tentacles and a short flat median lobe. In the resting state the inner pair of tentacles measure 3.7 mm. long, the outer pair 2.9 mm. and the median lobe 1.4 mm. Two eyes, situated about 2.0 mm. from the base of the median lobe, are present. The mouth is in the usual position on the ventral surface and about 2.0 mm. from the front. The sucker is large measuring about 2.6 mm. in diameter. Its posterior margin is overlapped by the end of the body. The genital aperture is slightly in front of the sucker.

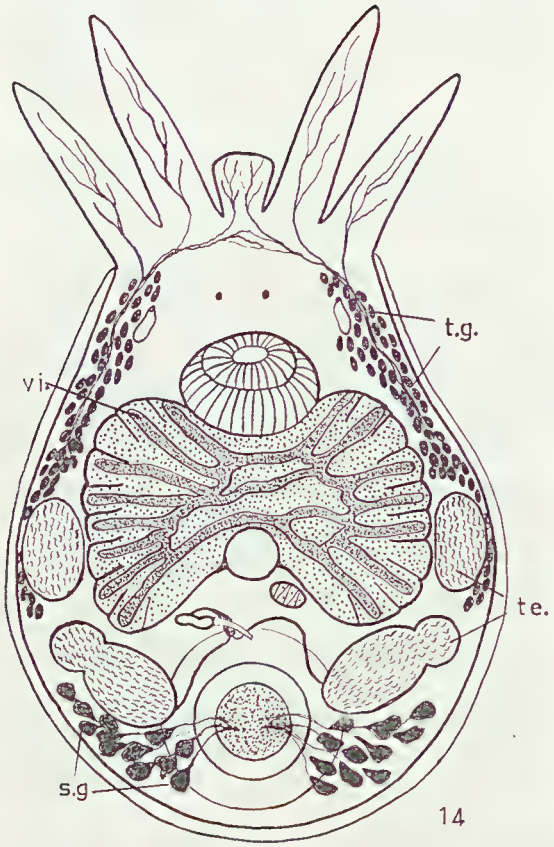
Body-wall and Integumentary Glands. The usual integumentary layers are present. The cuticle is about 3μ in thickness. Its surface is raised into numerous small conical papillae and perforated by minute pores. The epidermis is about 15μ thick. In section it is striated and appears to consist of vertical fibrillae. The nuclei of the epidermis are oval and measure about 21μ x 15μ. They are widely scattered. The basement membrane is about 7μ in thickness. No cilia were found on the integument.

The dermal muscular sheath consists of a layer of transverse or circular muscles immediately internal to the basement membrane. Internal to the circular muscles is a much thicker layer of longitudinal muscles and between the two a thin layer of diagonal fibres. Numerous pigment granules lie in the parenchyma internal to the longitudinal muscles. The largest granules are about 6μ in diameter. In the region between the front of the pharynx and the anterior end of the body is a second layer of circular muscles. This layer is dorsal to the layer of ventral longitudinal muscles. Numerous dorso-ventral fibres occur throughout the body. Most of the muscles appear tubular in section with a deeply staining cortex surrounding a non-staining core. Brandes (1892) observed a similar condition in the muscles of *Temnocephala brevicornis* Monticelli. However, Haswell (1893) considers the tubular appearance of the muscles to be due to unsatisfactory fixation and says it " is rarely seen in specimens that have been fixed by means of a corrosive sublimate or osmic acid solution ". The specimens of *T. quadricornis* on which the present description is based were fixed in Apathy's fluid, which contains corrosive sublimate.

The tentacular or rhabdite glands extend along each side of the body from in front of the excretory vesicles to the posterior testes. The nuclei of the cells are about 36μ in diameter and the rhabdites 6μ in length. The sucker glands lie on each side of the posterior part of the body. They are larger than the tentacular glands and somewhat irregular in shape. Their ducts converge on the stalk of the sucker.

Digestive System. The mouth leads into a short pharyngeal pouch with strongly folded walls. The pharynx has the usual form of a pharynx bulbosus. It is about 1.10 mm. long and 1.52 mm. wide. The posterior sphincter is more strongly developed than the anterior one. A number of ganglion cells and a few gland cells occur among the radial muscles. Posteriorly the pharynx leads into a short oesophagus, which is surrounded by a large number of unicellular oesophageal glands. As in other species the intestine has the form of a somewhat rectangular sac. The anterior wall forms a pouch-like projection on each side of the pharynx. The posterior wall forms a concavity round the vesicula resorbens. The lumen of the intestine has nine septa on each side (Text-fig. 14). The outer surface exhibits corresponding constrictions. When fully formed the cells of the intestinal epithelium are elongate and club-shaped. The cell nuclei are basal in position. However, in some cases cell walls are absent and the epithelial lining forms a syncytium.

Excretory Bladder. The two apertures of the excretory system open on the dorsal surface, one on each side, in a transverse plane slightly behind the eyes. They are about 1.10 mm. from the margin. The bladders are long and pyriform, measuring



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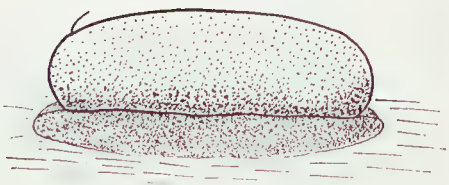

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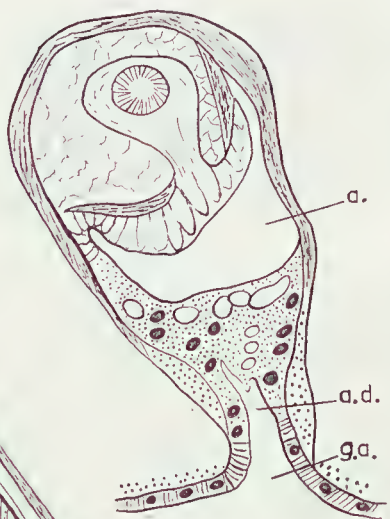

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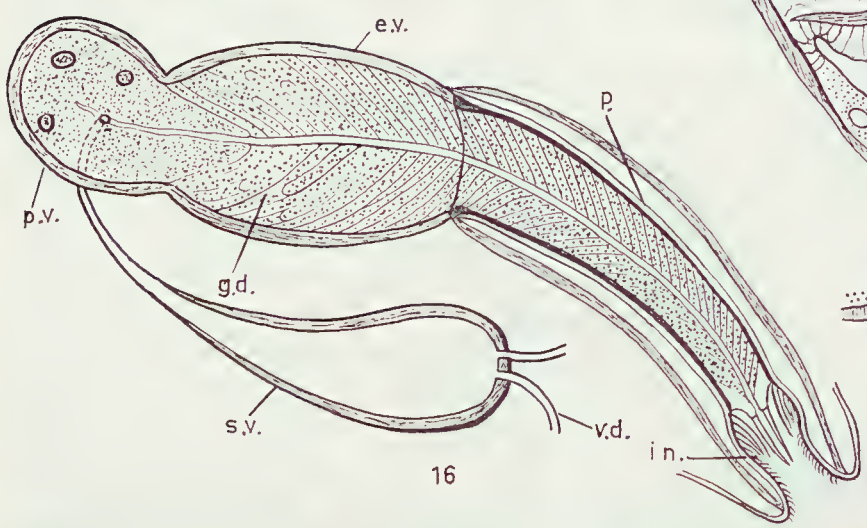

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Temnocephala quadricornis Haswell.

FIG. 14.—General view of external and internal features.
Fig. 15.—Section of eye with surrounding nerve cells.
Fig. 16.—Longitudinal section of male reproductive organs.
Fig. 17.—Sagittal section of atriumh and atrial duct showing syncytial plug.
Fig. 18.—Egg viewed from the side.

about 520μ in length and 190μ in width. At the base each vesicle is bent on itself, and gradually narrows to form a tubular portion, which curves posteriorly and branches to form two main excretory vessels. One of the vessels bends upward and runs longitudinally above the intestine, the other bends downwards and runs longitudinally below the intestine. Closely applied to the posterior surface of the bladder is a large myoblast. At the base of the vesicle, where it is bent on itself are two nuclei. The wall of the bladder is thick and densely fibrous. It is furnished with few canals. The whole vesicle has a thin muscular investment. A number of large excretory cells occur in the parenchyma, especially near the dorsal surface above the reproductive system. The cytoplasm of the cells is traversed by numerous minute canals and in some cases definite cell-walls are absent. The nuclei are oval and large measuring 57μ x 42μ.

Nervous System. The structure of the brain and the distribution of the main nerve cords are much the same as in other species. The brain consists of a transverse mass of nerve fibres and is situated in front of the pharynx. On each side it curves slightly backward and downward. Arising from the front of the brain are two stout nerves which pass forward, one on each side of the eyes, and give off branches to the tentacles and median lobe. The usual dorsal, dorsolateral and ventral longitudinal nerves are given off from each side of the brain and pass backward. The dorsal longitudinal nerves extend upward, one on each side of the front of the pharynx, and run posteriorly above the intestine, uniting near the end of the body. The dorsolateral longitudinal nerves pass upwards and backwards behind the excretory bladder. They lie external to the anterior testes in the angle between the testes and the dorsal body wall. The ventral longitudinal nerves pass downwards at the sides of the pharynx and continue posteriorly at the sides of the intestine. They lie in the angle between the lower surface of the anterior testes and the intestine.

The two eyes are 430μ apart and situated above the front of the brain. Each consists of a pigmented cup about 90μ in diameter. The mouth of the cup is filled with a spherical refractive body (Text-fig. 15). The base of the cup is occupied by a single retinula cell. The refractive body has a somewhat fibrillar structure and is capped by a ganglion cell. The eye lies somewhat transversely with the refractive body directed outwards. Above and slightly in front of the eye is a large bipolar nerve cell.

In front of the brain are the usual two pairs of large cells, one pair more or less above the other. Their cytoplasm has a fibrillar structure and is traversed by numerous muscle strands. A distinct cell wall appears to be absent. The nuclei are oval and measure about 75μ x 60μ.

Reproductive System. In the male system there are two pairs of testes, an anterior pair and a posterior pair. The anterior testes lie one on each side of the intestine. They are oval in shape and measure 1.12 mm. long and 0.822 mm. wide. The posterior pair are situated, one on each side, behind the intestine (Text-fig. 14). They are bilobed and measure 1.46 mm. long and 0.85 mm. wide. The two testes on each side are united by a short seminal duct.

The vasa deferentia arise ventrally from the inner lobe of the posterior testes. The vas deferens from the left testis passes directly to the base of the seminal vesicle, that from the right testis bends round in front of the atrium before reaching the vesicle. They enter the vesicle separately.

The seminal vesicle is situated more or less obliquely below the penis. It is elongate and pyriform in shape, measuring about 1.01 mm. long and 0.27 mm. in diameter at its widest part. Its wall is very stout being about 45μ in thickness and is formed mainly of circular muscles surrounding a thin layer of longitudinal muscles. The lumen has a thin protoplasmic lining with a few scattered nuclei. The distal end of the vesicle narrows to form a short seminal duct, which enters the anterior surface of the prostate vesicle.

The prostate vesicle is a rounded sac-like structure about 0.24 mm. in diameter (Text-fig. 16). It has thick muscular walls and its lumen is almost obliterated by a dense mass of finely fibrous protoplasm containing a few nuclei but no cell boundaries.

The ejaculatory vesicle is about 0.26 mm. in diameter and 0.58 mm. long. It is separated from the prostate vesicle by a slight constriction, but both vesicles have a similar and continuous muscular wall. The ducts of the granule glands enter on the anterior side below the junction with the prostate vesicle. On entering they surround the ejaculatory duct and extend into the penis.

The penis lies on the left side of the median plane. It slopes obliquely downward to open into the left side of the atrium. It is supported by the usual chitinous tube and is about 0.97 mm. long. At the base it is 0.21 mm. wide but tapers to 0.13 mm. at the apex. The introvert is about 0.30 mm. long and somewhat swollen in the proximal half. In the inverted state it is thickly lined with spines. Those lining the apical half are very short being only 9μ long. Those lining the basal half increase in length proximally from 30μ to 120μ. Several very long curved spines are attached to the end of the ejaculatory duct at the base of the introvert. These spines are about 210μ in length. When the introvert is half everted, they project into the atrium.

The granule glands are situated on each side of the intestine and extend from the excretory vesicle to the posterior testes. Some also lie along the courses of the vasa deferentia and at the sides of the seminal vesicle. Their ducts enter the ejaculatory vesicle through numerous small apertures on the anterior side near the junction with the prostate vesicle.

In the female reproductive system the germarium lies on the right of the median plane close behind the intestine. It is more or less ovoid in shape and measures 390μ long and 260μ wide. The germiduct is very short and the germarium opens almost directly into the right side of the ootype. The ova have the characteristic wedge shape.

The vasicula resorbens is a pyriform or almost spherical sac incorporated in the posterior wall of the intestine. It measures about 312μ in diameter. Haswell (1924) has described and figured a tempor-

ary genito-intestinal canal leading from the front of the vesicle into the intestine. In the sections of one of the specimens examined in the present study part of the anterior wall of the vesicle is broken down, but the epithelium of the intestine is intact. Since the vesicle is almost empty it may be assumed that the canal is in process of closing. Posteriorly the vesicula resorbens gives rise to a short duct, about 130μ in diameter, which becomes continuous with the ootype.

Four receptacula seminis are arranged more or less symmetrically round the ootype slightly anterior to the opening of the germiduct. Each receptaculum is a finger-like diverticulum measuring 150μ long and 48μ wide, and possessing strong muscular walls.

Behind the entrance of the germiduct the ootype bends downwards and expands to form the uterus, which is almost vertical in position. Ventrally the uterus narrows giving rise to a short vagina which runs horizontally to enter the right side of the atrium. The uterus, ootype and vagina all have thick muscular walls. Numerous shell glands open into the uterus. The glands tend to fuse with one another forming a composite gland with several ducts.

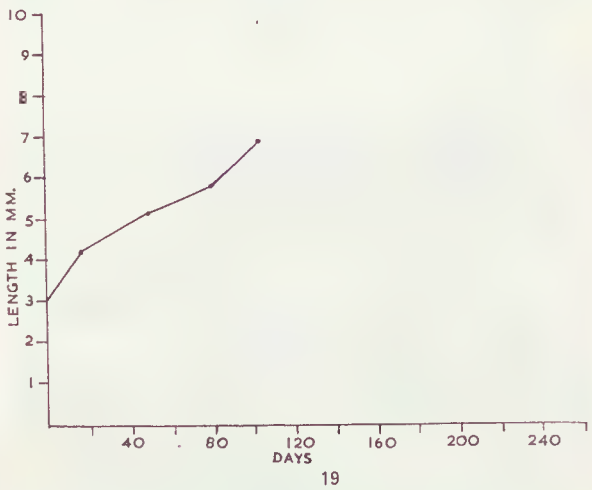
The vitellarium consists of a number of slender lobes above and below the intestine. The lobes are more numerous dorsally than ventrally and tend to lie transversely. Some of them branch and form anastomoses. On each side of the posterior wall of the intestine the vitellarium gives rise to a vitelline duct. The two ducts converge on the ootype, which they enter near the openings of the receptacula seminis.

The atrium is a large sac-like structure disposed transversely. It is 0.78 mm. wide, 0.52 mm. high and 0.43 mm. from front to back. Its walls are strong and muscular with fibres running in all directions. When not distended by the presence of an egg, the walls are strongly folded. A number of atrial glands open into the atrium. They probably supply the cementing material by which the egg is attached. From the ventral side of the atrium a short atrial duct, surrounded by strong sphincter muscles, leads to the genital aperture. Between periods of reproductive activity the duct is closed by a plug, which seems to be derived from the epidermis (Text-fig. 17). It has the form of a syncytium containing a number of nuclei and vacuoles. It seems probable that the long curved spines, present in the introvert of the penis, are used to pierce the plug during copulation.

Host and Localities. *T. quadricornis* has been found only on the large fresh-water crayfish, *Astacopsis gouldi* (Clerk). Specimens of the crayfish taken in the Forth Falls rivulet (December, 1926), the Don River near Devonport (9th September, 1943) and Deep Creek near Smithton (30th January, 1966) were all found to be carrying the temnocephalid, which occurred mainly on the large chelae and the carapace.

Eggs and Incubation. The eggs are long, oval and very slightly reniform in shape. They measure about 2.91 mm. in length and 1.37 mm. in width. The capsule is dark brown and has a short slender projection from the upper surface near one end (Text-fig. 18). The eggs are usually deposited on the carapace, less frequently on the abdominal terga. They are often placed in grooves or depressions of the surface and may occur singly or in groups. The whole under surface of the capsule is cemented to the place of attachment. When hatching takes place, the upper surface of the capsule is torn open longitudinally.

Specimens of *T. quadricornis* kept under laboratory conditions failed to deposit eggs and hence the exact period of incubation could not be determined. However, it appears to be prolonged. Three eggs removed from the host on the 30th January, 1966, were successfully hatched in the laboratory. One required 136 days, another 166 days and the third 196 days. In the last case the average temperature of the water during the period was 13.9°C. It may therefore be assumed that the incubation period at that temperature is not less than 28 weeks.



Temnocephala quadricornis Haswell.

Fig. 19.—Graph showing growth of a specimen reared apart from its host from date of hatching, 15th June, 1966, to 30th September, 1966, that is for 107 days.

Rate of Growth. The newly hatched young are dark brown like the adult. When contracted they measure about 3.03 mm. long and 2.63 mm. wide, but are able to extend to a length of 5.7 mm. A specimen which hatched on 15th June, 1966, from an egg removed from the host was maintained under laboratory conditions and its rate of growth recorded (Text-fig. 19). In the 107 days from the date of hatching to 30th September, 1966, it increased in length from 3.03 mm. to 6.74 mm., both measurements being made on the contracted animal. The average temperature of the water during the period was 11.5°C. If the rate of growth is maintained, adult size should be reached in about 190 days from hatching.

Survival apart from the host. Specimens of *T. quadricornis* removed from the host and kept under laboratory conditions did not feed very readily and failed to survive for more than 76 days. However, specimens hatched in the laboratory were much easier to maintain. They fed readily on particles of the internal organs of flies and have survived for at least 107 days.

A small specimen about 4.0 mm. long was placed in 3.0 ml. of water in a small specimen tube and the tube firmly corked, as was done in the case of *T. tasmanica*. The specimen survived for 56 days without food, change of water, or admission of fresh air.

Temnocephala pygmaea sp. n.

(Text-figs. 20-26, Pl. I, fig. 3)

General Features. When alive and in a contracted state the largest specimens measure about 1.60 mm. long and 1.03 mm. wide. When fully extended they measure 2.57 mm. long. The body is colourless and more or less translucent. It is convex above and flat or slightly concave below. The margin is surrounded by a narrow transparent flange. There are four tentacles and a short flat median lobe (Text-fig. 20). The outer tentacles are about three quarters as long as the inner tentacles. Two eyes, situated about 342μ from the front, are present. The mouth is a rounded aperture in the normal position on the ventral surface and about 613μ from the front. The sucker is large being about 630μ in diameter. It is overlapped by the posterior end of the body. The genital aperture is very slightly in front of the sucker.

Body-wall and Integumentary Glands. The cuticle is smooth and about 1μ in thickness. The epidermis is about 6μ thick and in sections exhibits the usual vertical striations. The nuclei are oval and measure 5μ x 7μ. They are few and widely scattered. The basement membrane is slightly thicker than the cuticle. Numerous fine pore-canals pass through the integument. No cilia could be found on any part of the surface.

The dermal muscular sheath consists of a thin layer of circular fibres immediately below the basement membrane, an inner thicker layer of longitudinal muscles and an intermediate layer composed of a few diagonal fibres. Below the intestine the layer of ventral longitudinal muscles is more than twice the thickness of the dorsal layer, but becomes thinner laterally. Between the mouth and the front of the body there is a well developed layer of transverse muscles immediately internal to the layer of ventral longitudinal muscles. Numerous dorso-ventral fibres pass through the parenchyma in all parts of the body.

The tentacular glands are numerous and are distributed in a broad band along the sides of the body. They extend from immediately in front of the excretory bladders to the posterior testes. Fine strands of ducts from the glands pass forward and give off a number of branches, which enter the tentacles and median lobe. The rhabdites formed by the glands are about 6μ in length. The sucker glands occur on each side of the posterior end of the body and also in a transverse band in front of the sucker. Their ducts pass through the stalk and spread out radially to all parts of the sucker.

Digestive System. The mouth leads into a short prepharynx or pharyngeal pouch, which has strongly folded walls. The bulbous pharynx is relatively large and has a transverse diameter of 640μ and a length of 470μ. The posterior sphincter is much more strongly developed than the anterior sphincter. Some pharyngeal glands are present among the radial muscles, but are not numerous. The pharynx leads into a short oesophagus, which is surrounded by pyriform salivary glands. The opening into the intestine is encircled by a sphincter. The intestine has the usual form of a flat somewhat rectangular sac. In front it projects slightly on each side of the pharynx. Its posterior wall is concave round the vesicula resorbens. The lumen is partly divided by four pairs of septa which extend inwards from the lateral walls (Text-fig. 21). Corresponding constrictions of the intestine are very slight. The epithelium lining the lumen consists of elongate club-shaped cells filled with numerous rounded granules. The nuclei of the cells are basal in position. Externally the intestine is invested by a thin muscular layer.

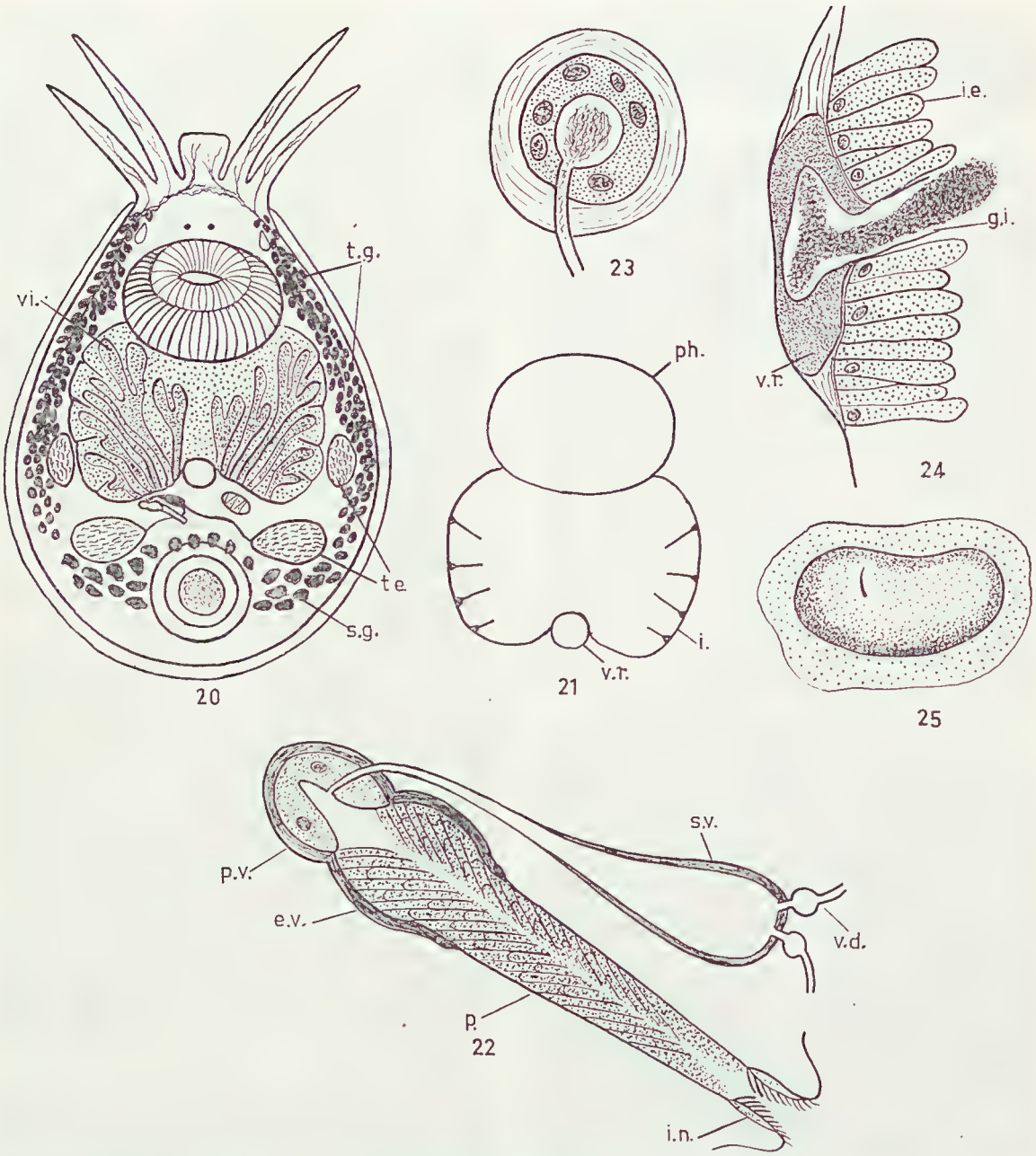
Excretory Bladders. The two excretory apertures are situated one on each side of the dorsal surface and in a transverse plane immediately behind the eyes. They are about 264μ from the margin. The bladder is somewhat pyriform, measuring 178μ long and 96μ wide. Its wall is thick and dense, with a number of small canals and vacuoles. Externally it is invested by a loose fibrous layer surrounded by a thin muscular sheath. The narrow inner end of the bladder is bent on itself. It gives rise to a short duct which divides to form two branches one of which passes forward and the other backward. Two nuclei are situated in the wall of the bladder near the inner end. A large spindle-shaped myoblast, which stains deeply with haematoxylin, is closely applied to the posterior surface of the bladder and extends from the external aperture almost to the inner end.

Nervous System. The brain consists of a transverse bar of fibrous nervous tissue surrounded by numerous ganglion cells. In front it gives off a pair of stout nerves, which pass forward and form branches which supply the tentacles and median lobe. The latter structure receives branches from both nerves. As in other species a pair of dorsal, a pair of dorso-lateral and a pair of ventral longitudinal nerves are given off from the sides of the brain. The dorsal longitudinal nerves are more slender than the others. They pass backward above the intestine and nearer to the median line than to the lateral margins. They are connected by a number of transverse commissures. The dorso-lateral nerves extend outwards from the brain and curve posteriorly behind the excretory bladders. They lie along the sides of the intestine and pass above the anterior testes and dorso-laterally to the posterior testes. The ventral longitudinal nerves extend downwards at the sides of the pharynx and continue towards the posterior below the sides of the intestine and ventral to the testes.

The eyes are situated above the front of the brain. They are separated by a distance of 99μ. Each has the form of a pigmented cup, 30μ in diameter, and poised obliquely. In the base of the cup is a single retinula cell, and in the mouth a more or less spherical refractive body.

In front of the brain are two large nuclei, about 21μ in diameter. They are situated in a common cytoplasm without a dividing cell wall.

Reproductive System. The male system consists of a pair of anterior testes, a pair of posterior testes, vasa deferentia, seminal vesicle, prostate vesicle, ejaculatory vesicle, penis and granule glands.



Temnocephala pygmaea sp. n.

Fig. 20.—General view of external and internal features.
Fig. 21.—Outline of digestive canal.
Fig. 22.—Longitudinal section of male reproductive organs.
Fig. 23.—Transverse section of prostate vesicle.
Fig. 24.—Parasagittal section of vesicula resorbens discharging contents through genito-intestinal canal.
Fig. 25.—Egg viewed from above.

The anterior testes are oval in shape and lie one on each side of the posterior half of the intestine. In mature specimens they measure 340μ long and 210μ wide. The posterior testes are also oval and lie one on each side in a transverse position behind the intestine. They are larger than the anterior pair and measure 410μ long and 270μ wide. From the posterior end of each anterior testis a

short duct passes to the outer end of the neighbouring posterior testis. The vas deferens from the right posterior testis arises ventrally from the inner end of the testis, passes transversely in front of the atrium, and enters the base of the seminal vesicle. The vas deferens from the left posterior testis is much shorter. It likewise arises ventrally from the inner end of the testis, passes in front of the penis and enters the base of the seminal vesicle. The two vasa deferentia enter close together but independently. Each is swollen into a small bulb before entry (Text-fig. 22).

The seminal vesicle is elongate and pyriform in shape, about 260μ long and 40μ in diameter at its widest part. It lies above or on the right side of the penis and is almost parallel with it. At its distal end it narrows forming a seminal duct which enters the prostate vesicle on the right side. The wall of the seminal vesicle has an outer layer of circular muscles surrounding an inner layer of longitudinal muscles. The lumen is lined by a thin layer of protoplasm.

The prostate vesicle (Text-fig. 22) is a rounded sac-like structure about 60μ in diameter. It is situated on the left side of the body, behind the intestine and close below the dorsal muscles. Its wall is strongly muscular and its lumen is lined with a thick layer of finely granular protoplasm containing a few nuclei, but no cell boundaries (Text-fig. 23).

The ejaculatory vesicle is a bulbous structure continuous with the prostate vesicle and penis. It has a stout muscular wall and is lined with a layer of protoplasm. On the right side, below the junction with the prostate vesicle, it is entered by the ducts of the granule glands. These ducts surround the central ejaculatory duct and extend into the penis (Text-fig. 22).

The penis is almost straight and is directed obliquely downwards from the ejaculatory vesicle to the left side of the atrium. The wall of the penis is supported by the usual chitinous tube, which is about 60μ in diameter at the base tapering to 30μ at the apex. The introvert is 78μ long and forms about one quarter of the length of the penis, which measures about 288μ long. The lumen of the introvert is lined with rows of sharp spines varying in length from 12μ to 60μ. The longer spines are nearer the base of the introvert and the shorter ones near the apex.

The granule glands are numerous. They form a lateral band lying below the rhabdite or tentacular glands. They also occur along the courses of the vasa deferentia and partly surround the seminal vesicle. Their ducts enter the ejaculatory vesicle as described above.

The female reproductive system includes the germarium, vesicula resorbens, receptacula seminis, ootype, uterus, vitellarium and various glands.

The germarium is oval measuring 102μ long and 81μ wide. It is situated behind the intestine and to the right of the median plane. The ova at the base of the germarium are small and rounded, those near the middle wedge-shaped and those near the entrance to the germiduct large and rounded. The germiduct is very short and leads directly from the inner end of the germarium into the dorsal side of the ootype.

The vesicula resorbens is normally a large rounded sac about 150μ in diameter. Its shape, however, depends to some degree on the contraction and extension of the animal. In some cases it is laterally compressed, in others compressed from front to back. It is incorporated in the middle of the posterior wall of the intestine. In some specimens the lining of the vesicle is thick and finely granular, in others it is vacuolated or very thin. The whole sac has a thin muscular investment. In one series of sections the genito-intestinal canal was open and the vesicle discharging its contents into the intestine (Text-fig. 24). Posteriorly a short duct from the vesicle becomes continuous with the ootype.

There are four receptacula seminis arranged round the ootype and opening into it slightly in front of the entrance of the germiduct. Each receptaculum is short and finger like, about 33μ long and 12μ wide. Its wall is thick and muscular being continuous with that of the ootype.

The ootype has thick muscular walls and small lumen. It runs posteriorly from the vesicula resorbens and after being entered by the receptacula seminis, the vetelloducts and the germiduct, it curves downwards and forwards enlarging to form the uterus. The latter has strongly folded muscular walls and is surrounded by a number of pyriform shell-glands. At its lower end the uterus forms a narrow vagina, which enters the right side of the atrium.

The vitellarium, when fully developed, has the form of slightly branched finger-like lobes situated above and below the intestine. The lobes are directed more or less longitudinally (Text-fig. 20). Those of each side unite posteriorly to form a vitelloduct. The two vitelloducts thus formed enter the ootype laterally near the entrance of the germiduct.

The atrium is an oval chamber lying slightly behind the genital aperture. When not distended by the presence of an egg it is about 75μ wide. However, it is capable of great expansion and when containing an egg it may occupy almost the whole space between the posterior testes, other organs being pushed out of place. Numerous large unicellular fusiform glands open into the atrium. The atrial duct slopes downward and forward. It is surrounded by strong sphincter muscles.

Locality and Host. This species was found on the large fresh-water crayfish, *Astacopsis gouldi* (Clark), taken at Britton's Swamp, near Smithton, Tasmania, 30th January, 1966. The temnocephalid occurred mainly on the third maxillipeds.

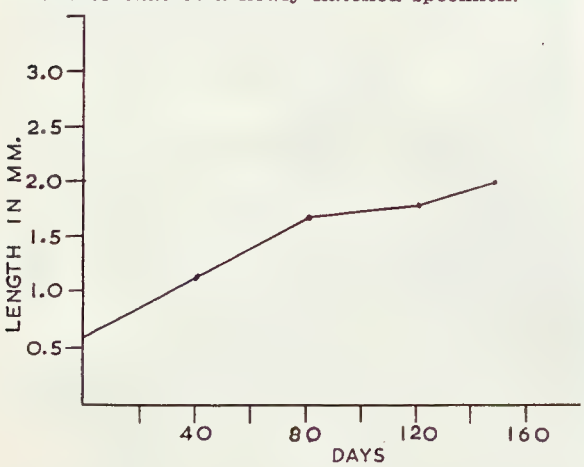
Eggs and Incubation. The egg is slightly reniform and measures about 0.57 mm. long and 0.30 mm. wide. It is enclosed in a pale yellowish-brown transparent capsule, which has a short slender projection on the upper surface about a third of the length from one end (Text-fig. 25). The whole of the under surface of the capsule is cemented to the place of attachment. The eggs are deposited on the sides of the carapace of the crayfish, especially in the marginal groove. Three eggs were laid by specimens of *T. pygmaea* kept in water in glass dishes in the laboratory. They hatched in 31 or 32 days, the average temperature of the water being between 19°C. and 20°C. (Table 3).

Table 3.

Egg	*Date laid*	*Date hatched.*	*Period of incubation in days.*	*Average Temperature of the water in degrees C.*
A	8 February, 1966	12 March, 1966	32	19.7
B	14 February, 1966	17 March, 1966	31	19.8
C	23 February, 1966	27 March, 1966	32	19.4

Rate of Growth. In the contracted condition newly hatched young are about 0.63 mm. long and 0.34 mm. wide. They are colourless and translucent. A specimen, which hatched from an egg removed from the carapace of the crayfish, was reared to full size in the laboratory in 152 days (Text-fig. 26). As in the case of preceding species it was fed on small particles of the internal organs of flies.

Survival apart from the host. Adult specimens removed from the crayfish and kept under laboratory conditions did not live longer than 59 days. However, specimens hatched and reared in the laboratory have survived for 222 days. An adult specimen, placed in 3.0 ml. of water in a small specimen tube and the tube then firmly corked, survived for 48 days without food, change of water or admission of air. During the period it decreased in size to that of a newly hatched specimen.



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Temnocephala pygmaea sp. n.

Fig. 26.—Graph showing growth of a specimen reared apart from its host from date of hatching, 31st January, 1966, to 24th July, 1966, that is for 152 days.

Temnocephala aurantiaca Haswell

(Text-figs. 27-32, Pl. I, fig. 4)

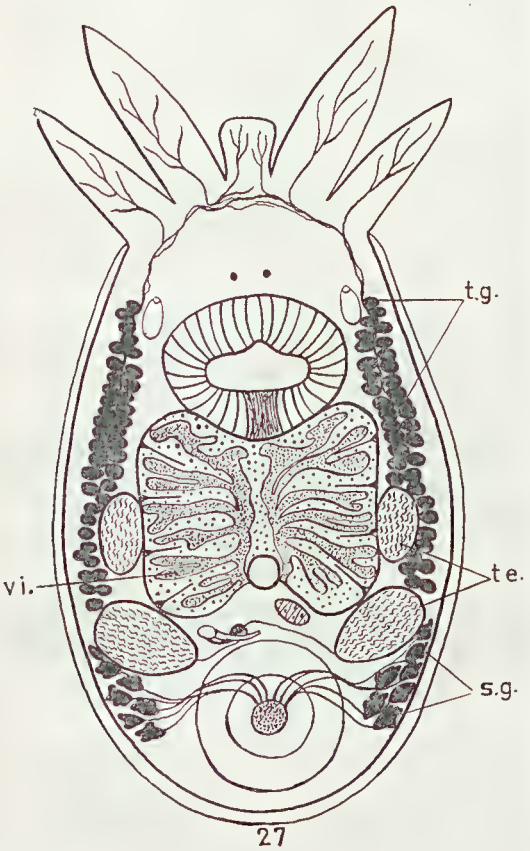
General Features. In the contracted state the largest specimens measure 2.57 mm. long and 1.31 mm. wide. However, they are able to extend to about 3.43 mm. in length. The body is convex above and flat below. The animal is more or less white with a yellow tinge on the dorsal surface. The extent of the colouration varies considerably in different specimens, but is generally well marked behind the intestine. Four tentacles and a short median lobe are present (Text-fig. 27). Two eyes are situated about 0.29 mm. from the base of the median lobe. The excretory apertures occur one on each side of the dorsal surface in a transverse plane slightly behind the brain. They are about 180μ from the margin. The mouth is in the usual position on the ventral surface and about 0.60 mm. from the front of the body. The sucker is 350μ in diameter. It is overlapped by the posterior end of the body. The genital aperture is usually about 75μ in front of the sucker, but in contracted specimens may be overlapped by the front margin of the sucker.

Body-wall and Integumentary Glands. The cuticle is about 3μ in thickness. It is smooth and perforated by numerous minute pores. In section the epidermis, which is about 6μ in thickness, has the usual striated appearance. The nuclei are widely scattered. They are about 7μ in diameter. The basement membrane is slightly thinner than the cuticle. No cilia were found on any part of the integument.

The dermal muscular sheath has the usual form. Immediately below the basement membrane is a thin layer of transverse or circular muscles. These surround a much thicker layer of longitudinal muscles. Between the two layers are a few diagonal fibres. On the ventral side the layer of longitudinal muscles is much more strongly developed than on the dorsal side. In front of the mouth there is a second layer of transverse muscles. This layer is internal to the ventral longitudinal muscles.

The tentacular or rhabdite glands form a longitudinal band on each side of the body and extend from the excretory vesicles to the posterior testes. Each band is made up of a large number of oval follicles, which measure about 45μ x 36μ. They are closely arranged and lie transversely. Fine thread-like ducts pass forward from the glands to the tentacles and median lobe, the latter receiving ducts from the glands on both sides of the body. The sucker glands are situated at the posterior end of the body and lie on each side behind the posterior testes. They are larger than the tentacular glands and somewhat lobed.

Digestive System. The mouth leads into a short pharyngeal pouch. The pharynx has the usual form of a pharynx bulbosus. It is about 440μ in diameter and 340μ long. The posterior sphincter is more strongly developed than the anterior sphincter. A few pharyngeal glands and ganglion



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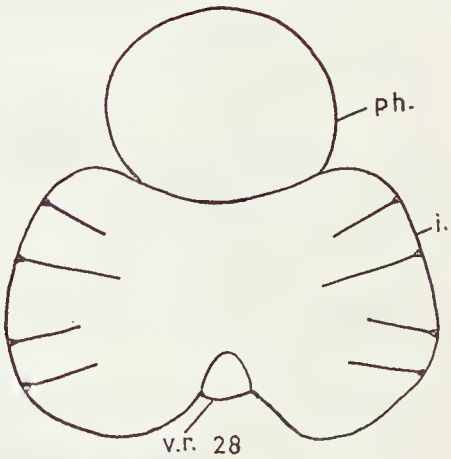

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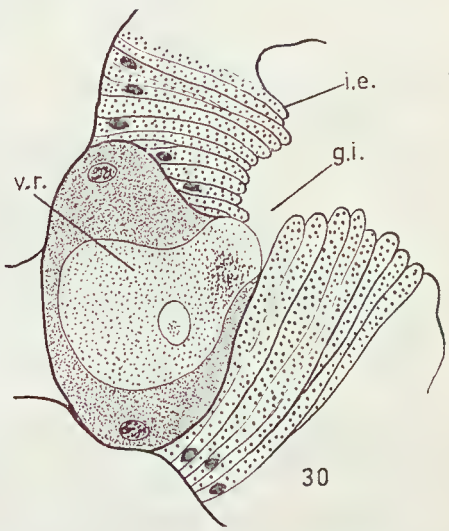

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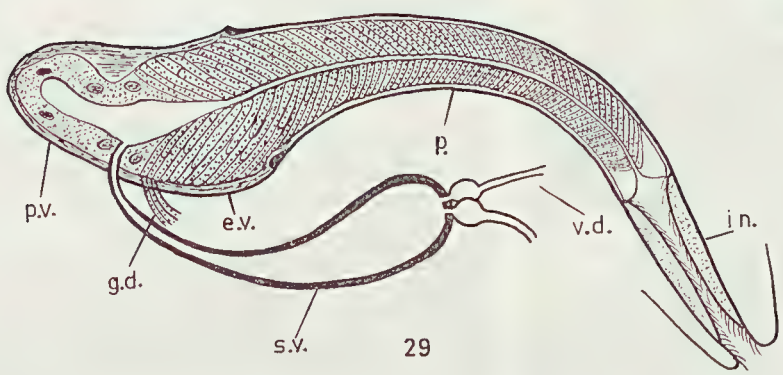

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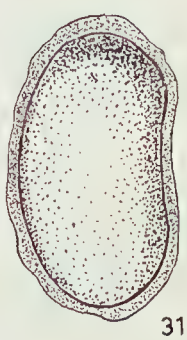

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Temnocephala aurantiaca Haswell.

Fig. 27.—General view of external and internal features.
Fig. 28.—Outline of digestive canal.
Fig. 29.—Longitudinal section of male reproductive organs.
Fig. 30.—Parasagittal section of vesicula resorbens with the genito-intestinal canal in course of formation.
Fig. 31.—Egg viewed from above.

cells are scattered among the radial muscles. Between the pharynx and intestine is a short oesophagus into which open a few pyriform salivary glands. The entrance of the oesophagus into the intestine is surrounded by a weak sphincter. The intestine is a more or less rectangular sac. Its anterior wall projects slightly on each side of the pharynx. The posterior wall is concave round the vesicula resorbens. Projecting into the lumen of the intestine on each side are four septa, thus giving rise to five pairs of lateral caeca (Text-fig. 28). The length of the intestine measured in the median plane is shorter than its width.

Excretory Bladders. The vesicles are situated one on each side of the front of the pharynx. Each is about 135μ long and 84μ in diameter and has the usual form. The thick wall surrounding the central lumen is strongly vacuolated or traversed by large canals. As in other species two nuclei are situated at the base of the vesicle.

Nervous System. The brain is a transverse fibrous mass of nervous tissue lying in front of the pharynx. It is about 210μ in width and is curved slightly downward and backward on each side. Anteriorly it gives off a pair of stout nerves, which pass outwards and forwards, dividing into branches, which enter the tentacles and median lobe. Arising from each side of the brain are the usual dorsal, dorso-lateral and ventral longitudinal nerves. In live lightly pigmented specimens the arrangement of the dorsal and dorso-lateral nerves may be readily observed through the integument. The dorsal nerves lie above the pharynx and intestine. They pass posteriorly, one on each side of the median plane, and unite behind the stalk of the sucker. The dorso-lateral nerves lie one on each side of the intestine. They extend posteriorly passing on the outer side of the dorsal half of the anterior testes. Numerous transverse commissures connect the dorsal nerves to each other and to the dorso-lateral nerves. The ventral longitudinal cords, which are much stouter than the others, pass downwards from the brain and extend posteriorly. They lie one on each side of the intestine and close to the ventral muscles. They continue posteriorly below the testes.

The eyes are situated immediately above the front of the brain. They are about 60μ apart and each has the form of a pigmented cup about 27μ in diameter. They are poised obliquely.

Immediately in front of the brain are two pairs of very large cells, one pair above the other. The upper pair are about 90μ in width and appear fused. Their cytoplasm is dense and fibrous. The nuclei are about 30μ in diameter and have a large nucleolus. The lower pair of cells are about 105μ in width and quite separate. Their cytoplasm is fibrous but not as dense as that of the upper pair and the fibres have a radial arrangement. Their nuclei are 24μ in diameter and have a somewhat smaller nucleolus.

Reproductive System. In the male system there are two pairs of testes, an anterior pair situated one on each side of the posterior half of the intestine, and a posterior pair situated obliquely behind the posterior lateral angles of the intestine. The anterior pair are oval in shape, 230μ long and 130μ wide. The posterior pair are somewhat broadly pyriform and larger than the anterior pair. They measure 310μ long and 180μ wide. A short duct leads from the ventral side of the hinder end of the anterior testis to the ventral side of the posterior testis, which it enters.

The vasa deferentia arise ventrally from the inner ends of the posterior testes. That from the left testis leads directly to the base of the seminal vesicle, whilst that from the right testis passes round the front of the atrium, before reaching the vesicle. The two vasa deferentia enter separately, and each forms a small bulbous expansion before entering (Text-fig. 29).

The seminal vesicle lies somewhat obliquely below the penis. It is elongate and pyriform, being about 180μ in length and 54μ in diameter at its widest part. Its distal narrow part forms a seminal duct, which opens into the under side of the prostate vesicle (Text-fig. 29).

The prostate vesicle is helmet-shaped, about 69μ long and 84μ wide. It has stout muscular walls and a thick lining of finely granular protoplasm with a few nuclei. In most specimens the vesicle is slightly bent to one side.

The ejaculatory vesicle is about 60μ long and 91μ in diameter. It is entered ventrally near its junction with the prostate vesicle by the ducts of the granule glands. The ducts surround the central ejaculatory canal and extend into the penis (Text-fig. 29). The figure given by Haswell (1900) does not differentiate between the prostate vesicle and the ejaculatory vesicle.

The penis (Text-fig. 29) has the usual structure. It is about 410μ long. The diameter is 90μ at the base and tapers to 18μ at the apex. The introvert is 120μ long and lined with needle-like spines, which vary in length from 11μ to 21μ. The longest spines are near the base and the shorter ones near the apex, when the introvert is inverted. The penis curves downwards and opens into the atrium dorsally almost above the genital aperture.

The granule glands lie on each side of the body below and sometimes between the tentacular glands. They extend from the excretory bladders to the posterior testes. Some are also situated along the vasa deferentia and at the sides of the seminal vesicle. Their ducts enter the ventral side of the ejaculatory vesicle as described above.

In the female reproductive system the germarium lies on the right side of the median plane close behind the intestine. It is ovoid in shape, about 90μ long and 60μ wide. The germiduct is very short and opens into the right side of the ootype.

There are four receptacula seminis. They are arranged more or less symmetrically round the ootype slightly anterior to the entrance of the germiduct. They are very short being but small pouches in the wall of the ootype.

Anteriorly the ootype leads by a very short duct into the vesicula resorbens, which is incorporated in the middle of the posterior wall of the intestine. The shape of the vesicle varies considerably. In some cases it is spherical and about 84μ in diameter, in others laterally compressed. It generally has a thick lining of finely granular protoplasm containing a few nuclei but no cell boundaries. Sometimes the lumen is divided into

an anterior and posterior compartment by a transverse septum. This partition may be developed prior to the formation of the genito-intestinal canal. The duration of the latter structure appears to be extremely short, since, although twenty-five specimens were examined in serial sections, not one was found to have the canal open. Several, however, showed it in process of formation (Text-fig. 30).

Behind the entrance of the germiduct the ootype bends ventrally and expands to form the uterus. At the lower end the uterus narrows forming a short vagina, which enters the right side of the genital atrium. The ootype, uterus and vagina have thick muscular walls and are surrounded by numerous fusiform unicellular glands.

The vitellarium consists of a number of branched lobes situated above and below the intestine. The lobes are mainly transverse in direction. They lead into a pair of vitelloducts, which open, one on each side, into the ootype near the receptacula seminis.

The genital atrium is a large transverse chamber with strong muscular walls. It is about 178μ in width and slopes upward on each side, its dorsal wall being depressed by the apex of the penis. Opening into the atrium are a number of atrial glands. The exit duct leading to the genital aperture is almost vertical and about 69μ in length.

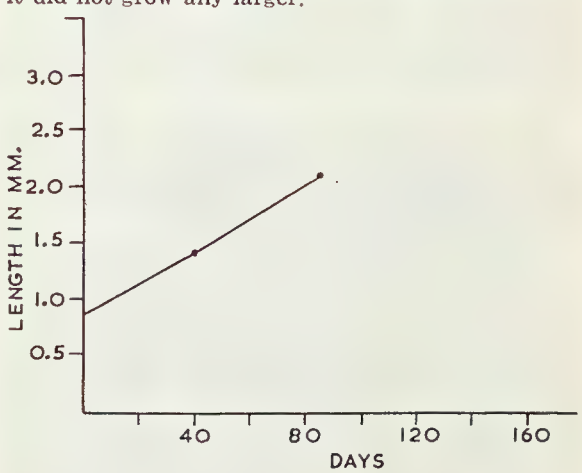
Host and Locality. The specimens of *T. aurantiaca* were found on the burrowing land-crayfish, *Engaeus cunicularius* Erichson, at Wayatinah, Tasmania, during October, 1960 and December, 1964. The crayfish had made their burrows in damp soil at the side of a small runnel flowing down a hillside in an area of rain forest. As many as 84 specimens of the temnocephalid were collected from a single crayfish. They occurred mainly on the carapace and thoracic appendages.

The specimens on which Haswell (1900) based his brief description are recorded as having been taken from an undetermined species of *Astacopsis* " found in burrows in damp ground in the neighbourhood of the Dee River towards the centre of Tasmania ". As a rule species of *Astacopsis* found in Tasmania do not make burrows in the soil. The Dee River is only about 12 miles from Wayatinah and *Engaeus cunicularius* is the most common burrowing crayfish in the locality. As Haswell's so-called *Astacopsis* was not determined and was found in a burrow, one may doubt the accuracy of the record.

Eggs and Incubation. The eggs of *T. aurantiaca* are pale cream in colour and enclosed in a pale yellow capsule. They are very slightly reniform in shape and about 620μ long and 370μ wide .(Text-fig. 31, Pl. I, fig. 4). A minute projection occurs on the upper surface of the capsule near one end. The projection is so small that it is easily overlooked. The eggs are deposited on the inner surface of the gill-cover of the crayfish. In one specimen of *Engaeus cunicularius* there were 100 eggs in the right and 90 in the left gill-chamber. The eggs are cemented by the whole under surface of the capsule. The upper surface splits open longitudinally when the young one hatches.

Adults of *T. aurantiaca* kept under laboratory conditions in glass dishes sometimes deposited their eggs in the dishes. However, the eggs failed to hatch and hence the exact period of incubation was not determined. Eggs removed from the gill-chamber of the host hatched readily. Fourteen eggs removed on 3rd December, 1964, were kept in water in the laboratory and the water renewed regularly. All the eggs hatched, the last one on 28th January, 1965. It would appear, therefore, that the incubation period during summer is not less than eight weeks.

Rate of Growth. A specimen of *T. aurantiaca*, which hatched on 4th December, 1964, from an egg removed from the host, was 0.74 mm. long and 0.40 mm. wide in the contracted state. It was kept in water in a small glass dish and fed on small particles of earth-worms and crushed flies. By the 31st March, 1965, that is after 117 days, it measured when contracted 2.05 mm. long and 0.97 mm. wide. Its rate of growth is shown in the graph (Text-fig. 32). Although maintained for another 207 days, it did not grow any larger.



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Temnocephala aurantiaca Haswell.

Fig. 32.—Graph showing growth of a specimen reared apart from its host from date of hatching, 4th December, 1964, to 31st March, 1965, that is for 117 days.

Survival apart from the host. Adult specimens removed from their host on 3rd December, 1964, and kept under laboratory conditions survived until 5th August, 1965, that is for 245 days. A specimen placed in 3.0 ml. of water in a small specimen tube and the tube firmly corked survived for 70 days without admission of air, renewal of the water, or provision of food.

Temnocephala fulva sp. n.

(Text-figs. 33-38)

General Features. In a contracted state the largest specimens are about 1.71 mm. long and 1.31 mm. wide. The widest part of the body is in the anterior half. The dorsal surface is strongly convex; the ventral surface flat or concave. The colour is mainly golden brown and is well marked on the anterior and posterior thirds of the dorsal surface. There are four tentacles and a short median lobe. The mouth and genital aperture are in the usual positions on the ventral surface. The sucker is

large being 560μ in diameter. Posteriorly it is overlapped by the end of the body. Two eyes are present and situated about 274μ from the base of the median lobe.

Body-wall and Integumentary Glands. The cuticle is smooth and slightly less than 3μ in thickness. The epidermis has the usual striated appearance. It is about 6μ thick and has a few scattered nuclei, which are about 7μ in diameter. The basement membrane has about the same thickness as the cuticle. The layer of circular muscles lying immediately below the basement membrane is very poorly developed and is not as thick as the epidermis. The layer of longitudinal muscles is much stronger and is somewhat thicker ventrally than dorsally. The intermediate layer of diagonal fibres is also better developed on the ventral side.

The tentacular or rhabdite glands lie in a longitudinal band on each side of the body and extend from the excretory bladders to the posterior testes (Text-fig. 33). They are oval in shape and measure about 48μ x 33μ. The rhabdites are less than 3μ in length. Ducts from the glands extend forward on each side and enter the tentacles and median lobe.

The sucker glands form a group on each side of the body behind the posterior testes. They are larger than the tentacular glands and somewhat lobed. Their ducts enter the stalk of the sucker and then spread out in the disk.

Digestive System. The mouth is a more or less circular aperture, 36μ in diameter, and about 160μ from the base of the tentacles. It leads into a short prepharynx. The pharynx has the usual bulbous form. It is 340μ in diameter and 310μ in length. A number of ganglion cells and pharyngeal glands are distributed among the radial muscles. The posterior sphincter is more strongly developed than the anterior sphincter. The oesophagus is short and its entrance into the intestine is surrounded by sphincter muscles. The intestine has the form of a flat, more or less rectangular, sac. In front it extends forward on each side of the pharynx. Posteriorly it extends backward for a short distance on each side of the vesicula resorbens. The lumen of the intestine is partially divided on each side by seven septa (Text-fig. 34).

Excretory Bladders. The apertures of the excretory system are situated on each side of the dorsal surface in a transverse plane slightly in front of the pharynx. They are about 260μ from the lateral margin. The excretory vesicles lie one on each side midway between the pharynx and the side of the body. Each is somewhat rounded, measuring 120μ long and 110μ wide. Close to the anterior surface of the vesicle is a large fusiform myoblast, which stains deeply with haematoxylin.

Nervous System. The brain lies in the normal position in front of the pharynx. It has the form of a transverse bar of nerve fibres and is about 270μ wide. Anteriorly it gives rise to a pair of stout nerves, that pass forward and divide forming branches, which go to the tentacles and median lobe. Arising from each side of the brain are the dorsal, dorsolateral and ventral longitudinal nerves. The dorsal nerves pass backward above the intestine, one on each side of the median plane, and unite near the posterior end of the body. The dorsolateral pair are situated on each side of the intestine. They lie close below the dorsal musculature and on the inner side of the anterior testes. The ventral pair pass downward, one on each side of the pharynx, and extend posteriorly close to the ventral musculature and at the sides of the intestine.

The eyes have the usual form of pigmented cups about 24μ in diameter and 78μ apart. The base of the cup is occupied by a single retinula cell and the mouth of the cup by a spherical refractive body.

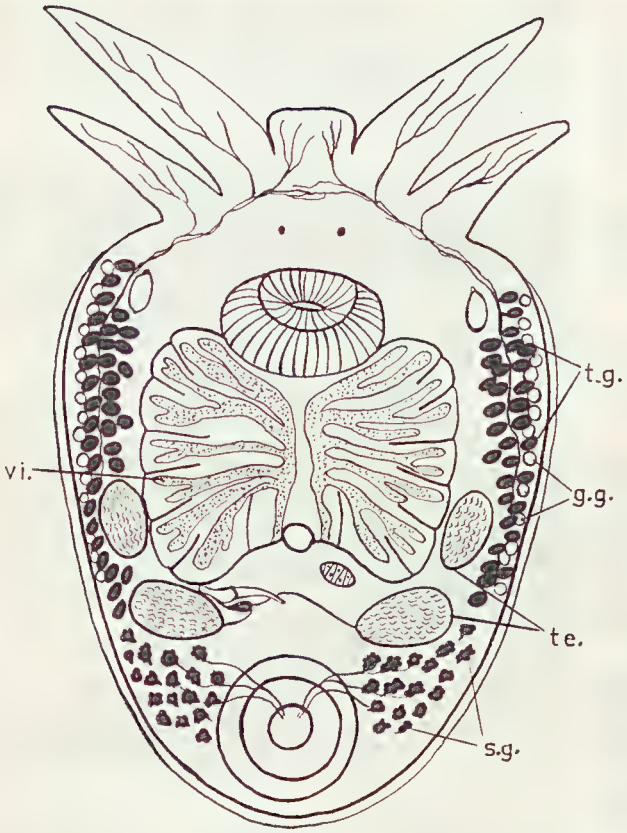
As in the other species two pairs of large cells, one pair above the other, occur close in front of the brain (Text-fig. 35). The upper pair are irregular in shape, without definite cell walls and appear fused. Their cytoplasm is very dense, finely fibrous and stains pink with eosin. Their nuclei are oval measuring 27μ x 21μ. The lower pair of cells are rounded and somewhat lobed. They are separate and have definite walls. Their cytoplasm is less dense and stains bluish with haematoxylin but does not stain with eosin. The nuclei measure 24μ x 18μ. Numerous muscle fibres pass through both pairs of cells. As mentioned under *T. cita* these cells do not appear to form part of the nervous system. They may be paranephrocytes and excretory in function but are always closely associated with the brain.

Reproductive System. In the male system there are four testes, an anterior pair and a posterior pair. The anterior pair are situated one on each side of the posterior half of the intestine. They are oval and up to 340μ in length and 120μ in width. The posterior pair are situated one on each side behind the intestine. They are somewhat pyriform in shape and have the narrow end directed inwards. They measure up to 340μ in length and 160μ in width. On each side a short duct passes from the anterior to the posterior testis. The vasa deferentia arise from the inner ends of the posterior testes. That from the left testis bends forward and passes directly to the base of the seminal vesicle, whilst that from the right testis curves round the front of the atrium before reaching the vesicle. The two vasa deferentia enter the vesicle separately, but close together. Each is slightly expanded before entry.

The seminal vesicle (Text-fig. 36) lies more or less transversely below the penis. It is elongate and pyriform in shape, about 220μ long and 60μ wide. Its distal end narrows to form a seminal duct, which enters the prostate vesicle ventrally.

The prostate vesicle lies on the left side close behind the intestine and immediately below the dorsal musculature. It is somewhat conical or helmet-shaped, 116μ long and 72μ wide at the base. It has a strong muscular wall and a thick protoplasmic lining, which is finely granular. A few nuclei are found in the lining but no cell boundaries. Externally the prostate vesicle merges into the ejaculatory vesicle without any distinct demarcation. It receives the duct from the seminal vesicle near its base.

The ejaculatory vesicle is about 92μ long and, when not distended, 81μ wide. It is entered ventrally near its junction with the prostate vesicle by the ducts of the granule glands. The ducts surround the ejaculatory canal and extend into the penis.



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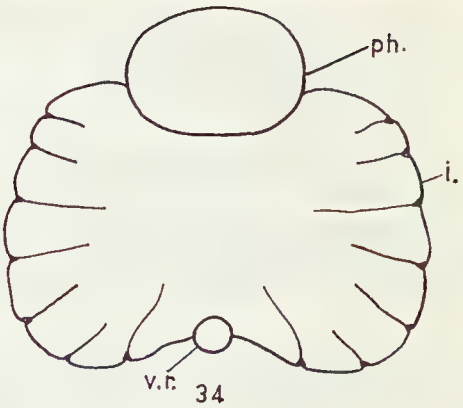

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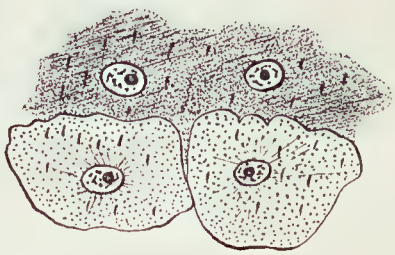

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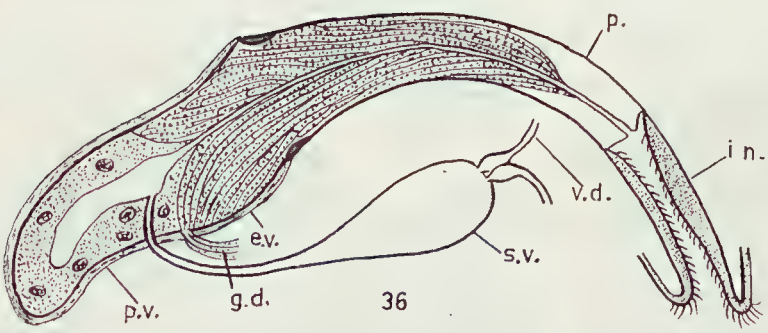

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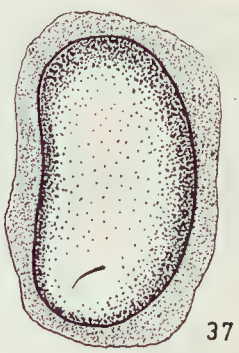

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Temnocephala fulva sp. n.

Fig. 33.—General view of external and interal features.
Fig. 34.—Outline of digestive canal.
Fig. 35.—Transverse section through two pairs of large cells in front of brain.
Fig. 36.—Longitudinal section of male reproductive organs.
Fig. 37.—Egg viewed from above.

The penis lies more or less transversely on the left side of the body behind the intestine. It has the usual form and is about 405μ long. Its diameter at the base is 81μ and tapers to 30μ at the apex. The introvert is 135μ long, thus forming one third of the length of the penis. The spines lining the introvert are very short being only about 6μ in length. They are uniform in size, except those

at the apex which are a little longer. The penis curves downward and projects into the left side of the atrium (Text-fig. 36).

The granule glands are distributed along the sides of the body and are mostly below the tentacular glands. They also occur along the vasa deferentia and at the sides of the seminal vesicle. Their ducts enter the ejaculatory vesicle as described above.

In the female system the germarium lies on the right side of the body close behind the intestine. It is about 105μ long and 60μ wide. It opens by a very short germiduct into the right side of the ootype.

There are four receptacula seminis. They are small and finger-like. The largest is 24μ long and 9μ wide. They are arranged round the ootype and open into it anterior to the entrance of the germiduct.

The anterior end of the ootype forms a short duct leading to the vesicula resorbens. The latter is a laterally compressed sac incorporated in the middle of the posterior wall of the intestine. Its transverse diameter is 90μ and its dorsoventral diameter 165μ. The lumen is small owing to the presence of a thick protoplasmic lining, which is finely granular and provided with a few nuclei. The opening into the vesicle is surrounded by the usual radial and sphincter muscles.

Behind the entrance of the germiduct the ootype bends ventrally and enlarges to form the uterus. At its lower end the uterus narrows giving rise to a short vagina, which enters the right side of the atrium. The ootype, uterus and atrium have strong muscular walls and are surrounded by a number of fusiform unicellular glands, which stain deeply with haematoxylin.

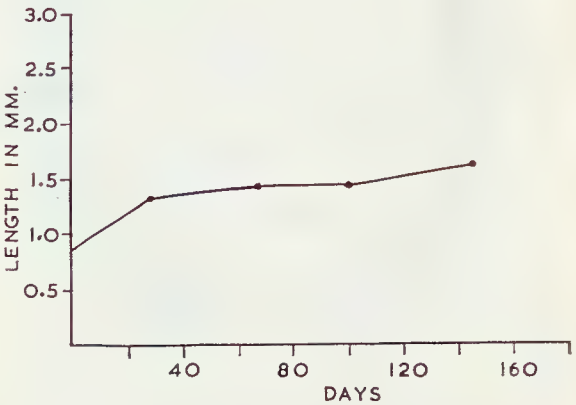
The vitellarium consists of a number of branched lobes situated above and below the intestine. Most of the lobes are directed transversely (Text-fig. 33). Posteriorly the vitellarium gives rise to a pair of vitelloducts, which open, one on each side, into the ootype near the entrances of the receptacula seminis.

Host and Locality. Thirteen specimens of *T. fulva* were taken from the land-crayfish, *Parastacoides tasmanicus* (Erichson), found in burrows in damp soil sear Lake Pedder, Tasmania, 25th February, 1966. The temnocephalid occurred mainly on the carapace and large chelae of the crayfish.

Eggs and Incubation. The eggs are pale yellow and enclosed in yellowish brown capsules. They are very slightly reniform and measure 630μ long and 370μ wide (Text-fig. 37). The upper surface of the capsule has a short curved projection about one fifth of the length of the egg from one end. The eggs are deposited singly in the gill-chamber. They are placed on the inner wall of the branchiostegite and cemented for the full length of the under surface of the capsule.

No eggs were laid by specimens of *T. fulva* kept apart from their host under laboratory conditions and hence the exact period of incubation could not be determined. However, twelve eggs removed from the gill-chamber of the crayfish were kept in water in small glass dishes, the water being changed every one or two days. Eleven of the eggs hatched. The longest time required by any one of them was 63 days, the average temperature of the water being 16.8°C. It may be assumed, therefore, that at that temperature the incubation period is not less than nine weeks. In the process of hatching the capsule ruptures more or less longitudinally on the upper surface.

Rate of Growth. The newly hatched young are white and translucent. When contracted they usually measure about 0.857 mm. long and 0.571 mm. wide. A specimen which hatched on 25th April, 1966, was reared to maturity in the laboratory by feeding it with small particles of the internal organs of flies. It lived for 146 days and grew to a length of 1.60 mm, and a width of 0.97 mm. when contracted. The rate of growth is shown in the graph (Text fig. 38).



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Temnocephala fulva sp. n.

Fig. 38.—Graph showing growth of a specimen reared apart from its host from date of hatching, 25th April, 1966, to 18th September, 1966, that is for 146 days.

Survival apart from the host. Adult specimens removed from their host and maintained under laboratory conditions did not thrive and failed to survive longer than a month. However, as indicated above, young ones hatched in the laboratory live much longer.

DISCUSSION

The ability of various species of *Temnocephala* to survive for some time after removal from their hosts has been mentioned by a number of authorities, notably, Philippi (1870), Weber (1889), Chilton (1889), Haswell (1893), Goetsch (1935), Pereira & Cuocolo (1941) and Fyfe (1942). In most cases, however, no exact data on the duration of survival apart from the host are given. For example Haswell (1893) simply states that the forms with which he had the opportunity of experimenting were "able to live for a very long time, it might be almost said indefinitely after removal from the surface of their host". Chilton (1889) records specimens of *T. novaezealandiae* as living for months apart from their host. Pereira & Cuocolo (1941), on the other hand, provide more definite information on *T. brevicornis* Monticelli, which normally lives on the integument of certain freshwater turtles in Brazil. They removed a number of

the temnocephalids from their hosts and kept them in small aquaria, feeding them on particles of tubificid and naidid worms. The temnocephalids survived for 71 days, and during this period deposited eggs in the aquaria. Some of the eggs hatched in 12 to 18 days. Most of the young did not survive longer than 15 days, but one lived for 93 days.

The Tasmanian species of Temnocephala described above varied in their ability to survive apart from their hosts. *T. cita* and *T. fulva*, both from the burrowing land-crayfish, *Parastacoides tasmanicus*, lived for about a month after removal from their host. However, *T. tasmanica* from *Astacopsis franklinii* has survived for 707 days and *T. aurantiaca* from *Engaeus cunicularius* for 245 days.

The nature of the relationship existing between temnocephalids and their hosts is obscure. Pereira & Cuocola regard *T. brevicornis* as being an inquiline, obtaining from its chelonian hosts shelter needed for its existence and food in the form of naidid worms, which occur on the integument of the turtles. An examination of the intestinal contents of *T. tasmanica* immediately after removal from its host showed that its normal food included chironomid larvae, nematodes, diatoms and *Stratiodrilus tasmanicus*. Of these, nematodes and *Stratiodrilus tasmanicus* are frequently found in the gill-chamber of the crayfish. Diatoms and chironomid larvae are probably stirred up from the bed of the creek during the movements of the crayfish in search of food. The normal food of *T. aurantiaca* includes Ostracods and Cyclopids, both of which occur in the mud in the burrows of *Engaeus cunicularius*. Under laboratory conditions and apart from their hosts both *T. tasmanica* and *T. aurantiaca* feed readily on particles of the internal organs of flies. The frequency with which many temnocephalids are found on or near the mouth-parts of their crustacean hosts suggests that they may share the food of their hosts by seizing small particles that float in the water, or which become caught on the setae of the oral appendages, while the crayfish is feeding. In the laboratory temnocephalids readily accept particles of food offered on the point of a needle, just as they might take it from the point of a seta.

Baer (1953) considers that the localization of the temnocephalid on its host ensures that it meets a continually renewed current of water needed to satisfy its oxygen requirement. He regards the association as a type of phoresy of an obligatory nature. Fyfe (1942) states that *T. novae-zealandiae* is able to live for several weeks in fresh-water without aeration. All the Tasmanian species were kept in water in small glass dishes. The water was changed occasionally, but no special aeration was provided and the dishes were covered. Furthermore as mentioned above a specimen of *T. tasmanica* lived in 3.0 ml. of water in a small corked tube for 100 days without food, change of water or admission of fresh air. Under similar conditions *T. aurantiaca* lived for 70 days, *T. quadricornis* for 56 days and *T. pygmaea* for 48 days. From these experiments it would seem that continuous aeration of the water is not such an important factor in considering the association of the temnocephalid with its host.

The opinion of Pereira & Cuocolo, that the obtaining of food and shelter are the main reasons underlying the association of the various species of Temnocephala with the animals that act as their hosts, is supported by the study of the Tasmanian species.

ACKNOWLEDGMENTS

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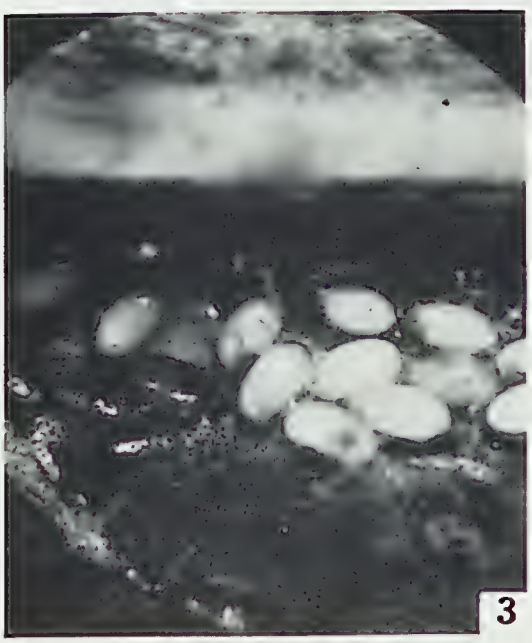
Abbreviations Used in Text-Figures.

a.—atrium
a.d.—atrial duct
a.g.—atrial glands
e.a.—excretory aperture
e.b.—excretory bladder
e.v.—ejaculatory vesicle
g.—germarium
g.a.—genital aperture
g.c.—ganglion cell
g.d.—ducts of granule glands
g.g.—granule glands
g.i.—genito-intestinal canal
i.—intestine
i.e.—intestinal epithelium
i.l.—intestinal lumen
in.—introvert
m.—myoblast
o.—ootype
p.—penis
ph.—pharynx
p.v.—prostate vesicle
r.b.—refractive body
r.c.—retinula cell
r.m.—retractor muscle
r.s.—receptaculum seminis.
s.g.—sucker glands
sh.g.—shell glands
s.v.—seminal vesicle
t.g.—tentacular glands
te.—testes
u.—uterus
v.—vagina
v.d.—vas deferens
vi.—vitellarium
v.r.—vesicula resorbens



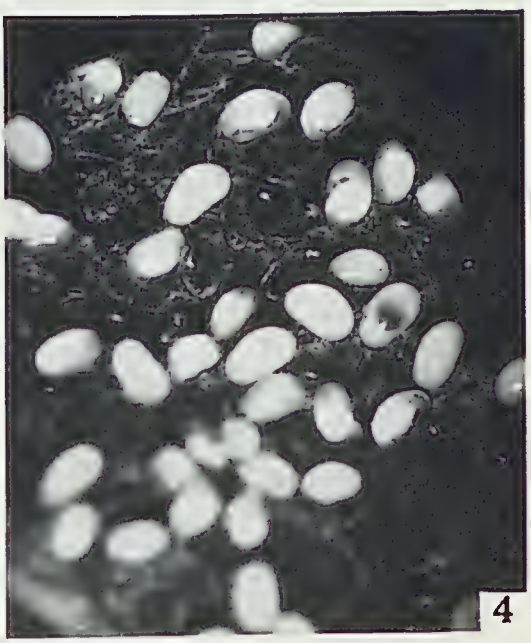


PLATE I.—

Fig. 1.—Eggs and empty capsules of *Temnocephala cita* sp. n. on pleopod of *Parastacoides tasmanicus* (Erichson). x 15.
Fig. 2.—Eggs of *Temnocephala tasmanica* Haswell in gill-chamber of *Astacopsis franklinii* (Gray). x 20.
Fig. 3.—Eggs of *Temnocephala pygmaea* sp n. on carapace of *Astacopsis gouldi* (Clark). x 20.
Fig. 4.—Eggs of *Temnocephala aurantiaca* Haswell on inner wall of branchiostegite of *Engaeus cunicularius* Erichson. x 15.

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TERTIARY DEEP LEAD DEPOSITS IN THE MOINA AREA

By

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with a Petrographic Note on Grey Billy by Dr. Germaine A. Joplin.

(With two plates and six text figures.)

ABSTRACT

Tertiary deep lead deposits in the Iris-Lea River Valley and the Basalt-Bell Creek Valley are described. Sediments total 280′ in thickness, have an upper layer of grey billy, and are capped by basalt and basaltic breccia. The bottom of the leads lies at up to 150′ below the level of the present drainage and a reversal of drainage direction may have taken place.

INTRODUCTION

The following information is the result of investigation of the Wilmot Power Scheme, a proposal to divert water from the Wilmot River to the River Forth as part of the Mersey-Forth Power Development.

The Tertiary deposits examined lie in the Iris-Lea River Valley and the Basalt-Bell Creek Valley, both of which lie in the trough of a broad, faulted basin folded in Ordovician rocks. The area forms part of the Department of Mines Sheffield Geological Sheet, which was published in 1959.

PHYSIOGRAPHY AND PHYSIOGRAPHIC HISTORY

The basin has strong topographic expression with the altitude of the rim, which is formed of Ordovician sandstones and quartzites, ranging from 2000′ to 3000′, whereas the trough, which contains Ordovician limestone, lies at about 1460′.

Both the Wilmot and Forth Rivers are actively degrading superimposed rivers that in general flow transverse to the structural trend. The River Forth is more deeply incised than the Wilmot River and at Cethana Damsite the bed of the River Forth lies at an altitude of 415′, whereas the bed of the Wilmot River lies at 1460′ at Wilmot Damsite.

Both river systems were affected by faulting and volcanic activity during the Tertiary. The probable course of the "Lorinna Lead" (Figure 2), the Tertiary ancestor of the River Forth, has been determined by Spry (1958) and by Burns and Gee (1962) from studies of the base of the Tertiary basalt. The basalt is thought to have flowed into the old valley system and displaced the drainage. Locally, as in the vicinity of Cethana Damsite, the present river occupies a similar position to the Tertiary stream, for Tertiary river gravels and lake sediments occur on both sides of the valley down to about 250′ above present river level. Also basalt tongues run into the Forth Valley and boulders of relic grey billy indicate the former presence of basalt.

The Wilmot River was similarly affected, but in this case a reversal of drainage direction seems likely. The probable course of the Tertiary stream (Figure 2) that was ancestral to the Wilmot River, the "Moina Lead", was determined by Burns and Gee (1962) by a study of the base of the basalt, and observations made during the investigation of the Wilmot Power Scheme are in agreement with their conclusions. Drilling on the spur adjacent to the left abutment of Wilmot Damsite (Plate 1) revealed the presence of a buried river channel (Figures 3 & 4) filled with Tertiary lake sediments capped by grey billy, and the course of the channel has been outlined by a resistivity survey. Similar sediments overlain by volcanic breccia were found by drilling above the proposed tunnel line in the Basalt Creek Valley (Figures 1 & 5), which lies between the Wilmot River and the Cradle Mountain Road. The extent of this deposit has been outlined by further drilling and by seismic refraction surveys.

At Wilmot Damsite the lowest point so far located on the channel bottom is at an altitude of 1330′, which is 130′ below the bed of the present Wilmot River. In the Basalt Creek Valley the lowest point located on the lake bed is at an altitude of 1550′, which is 150′ below the present creek bed.

The Wilmot River crosses a branch of the Tertiary river system immediately below the damsite, and the presence of soft sediment in the river bed and banks is the reason for the wide deep pond at this location. This buried channel, however, does not rejoin the Wilmot River further downstream, for a continuous exposure of bedrock occurs in the river bed for some miles downstream at a level well above the base of the Tertiary stream. A search was made along the northern rim of the basin for an outlet, but again continuous quartzite and sandstone outcrop precludes drainage in this direction. No outlet to the north was found from the Basalt and Bell Creek Valleys. Late Tertiary faulting may have elevated the divide, but when considered in conjunction with Burns and Gee's reconstruction of the "Moina Lead" it is reasonable to conclude that the buried channels flowed to the south before turning east to join the "Lorinna Lead".

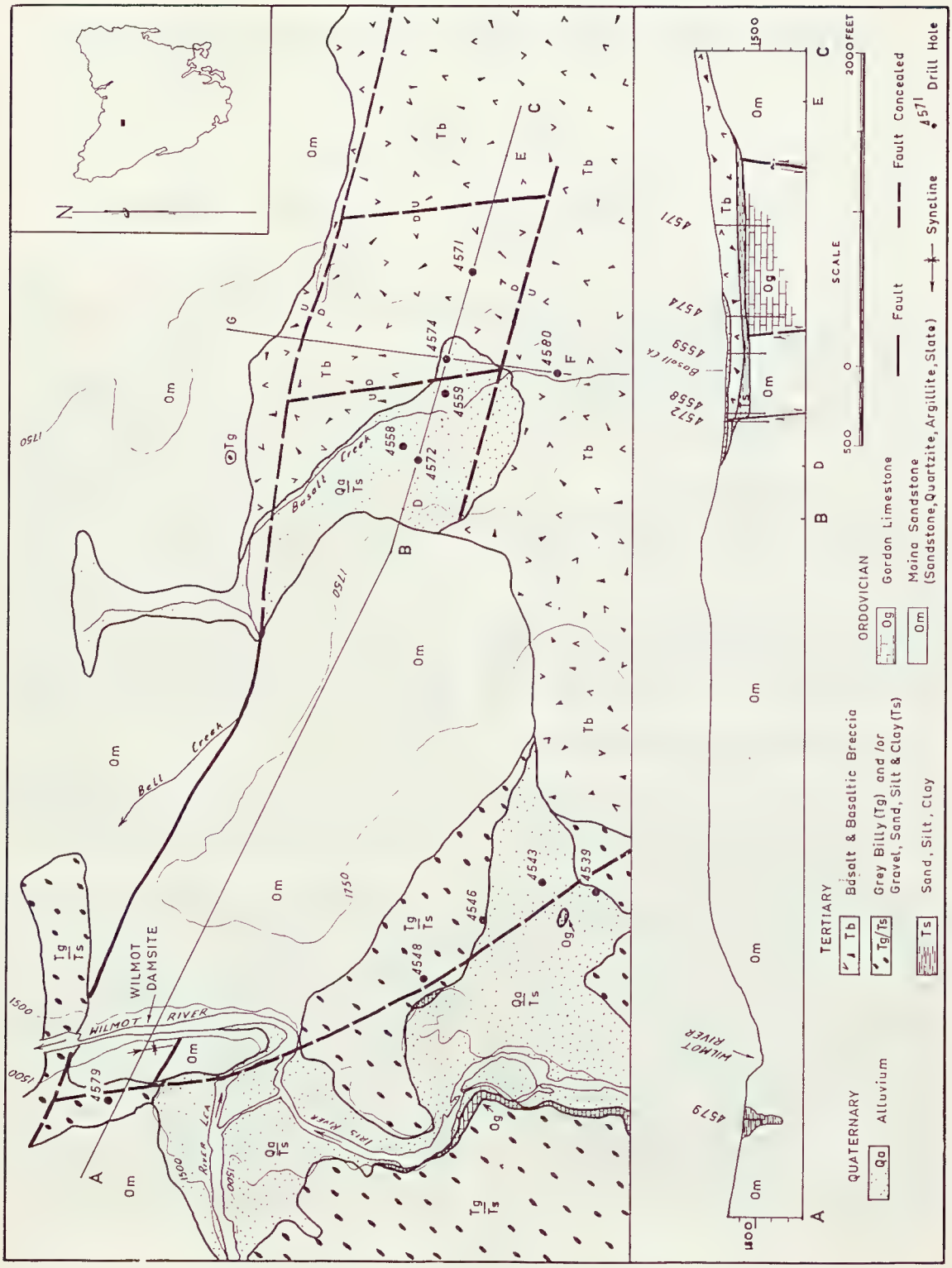

FIGURE 1.—Tertiary Deposits in the Moina Area.

The Tertiary stratigraphy indicates that disruption of the drainage system, probably by faulting, produced a system of lakes in which some 280' (Buried Channel-Wilmot Damsite) of sand, clay and gravel accumulated. Lacustrine sedimentation was followed by volcanic activity which covered the area with basaltic breccia and basalt flows causing further disruption of the drainage system.

STRUCTURE

The major structure is a broad faulted basin that trends N.N.W. and is approximately 6 miles long by 4 miles wide. It is folded in Ordovician Roland Conglomerate, Moina Sandstone and Gordon Limestone. Within the basin the rocks are folded into tight minor folds of wave length varying from 100' to 1000'. These folds are well exposed in the Lea and Wilmot River gorges, where they trend N.W. and plunge to the S.E. at between 5° and 25°. The synclinal ridge forming the left abutment of Wilmot Damsite is one of these folds.

Major faults trend in two directions. A N.N.W. trending fault controls the course of the buried channel on the western side of the damsite. A W.N.W. trending fault controls the buried channel that crosses the Wilmot River just downstream of the damsite. A W.N.W. trending normal cross-fault cuts the left abutment ridge just upstream of the damsite. A combination of these fault systems appears to define a fault trough in which the Ordovician limestone is preserved in the Basalt Creek Valley. The Tertiary lacustrine sediments are centered on and spill over from this trough.

STRATIGRAPHY

Ordovician

Moina Sandstone

The Moina Sandstone (Jennings, 1959) is the oldest formation exposed in the trough of the basin. It is correlated with the Caroline Creek Sandstone for which an Ordovician (Arenigian) age (Banks, 1961) has been established. The formation has been observed (Jennings, 1963) to conformably overlie the Roland Conglomerate on Mt. Roland.

In the Wilmot area the sequence consists of interbedded sandstones, quartzites, argillites, shales and slates. Spry (1963) examined specimens from drill holes on the damsite and penstock line and concluded that all appear to have been slightly thermally metamorphosed. This probably occurred during intrusion of the Devonian Dolcoath Granite, which outcrops on the River Forth just upstream of Cethana Damsite.

The sandstones are white, grey or pink and fine to medium-grained. Spry found them to be composed of angular to sub-rounded grains of quartz averaging 0.1 mm. in diameter surrounded by about 10% of matrix, which has been recrystallized to fine muscovite. The metamorphic mica is randomly arranged where it occurs with abundant quartz, but tends to be parallel to the bedding in the more pelitic types. Biotite, sericite and chlorite are present in the matrix of some specimens, and some are cut by sub-parallel to irregular fractures now filled with quartz. The sandstones grade into dense, white and saccharoidal quartzites. The argillaceous rocks grade from shales to argillites to slates.

At Wilmot Damsite a section totalling 170' has been measured. This section contains an upper member (80' thick) in which argillites, shales and slates are dominant and a lower member (90' thick) dominated by sandstone and quartzite. The base of the section is not exposed. Tubicolor and brachiopod casts are abundant.

Gordon Limestone

Isolated outcrops of limestone occur in the Iris River Valley and limestone was encountered in Drill Holes 4571 and 4574 (Figure 5) in the Basalt Creek Valley. The limestone is lithologically similar to and occupies the same stratigraphic position as the Gordon Limestone, which Jennings (1963) observed to conformably overlie the Caroline Creek Sandstone south and east of Standard Hill.

The limestone is banded light to dark bluish-grey, compact, hard and grades from a calcilutite to a calcarenite. It contains some argillaceous beds. Drill Holes 4571 and 4574 in the Basalt Creek Valley were completed in limestone and the maximum stratigraphic thickness measured was 240'.

Tertiary

Lacustrine Sediments

Drill Holes 4558, 4559, 4571, 4572 and 4574 in the Basalt Creek Valley (Figure 5) revealed the presence of Tertiary lacustrine sediments, soft black clay containing bands of dark grey and white fine-grained sand, underlying basaltic breccia and resting unconformably on Moina Sandstone and Gordon Limestone. A maximum thickness of 85' of sediment was found in Drill Hole 4558.

Similar clays and sands were encountered in the Iris River Valley in Drill Holes 4539, 4543, 4545 and 4548, and in Drill Holes 4565-68, 4577-79, 4581 and 4582 in the buried channel (Figure 3) on the western side of the left abutment of Wilmot Damsite. The lower part of the channel deposit is composed of light to dark grey, fine to medium-grained sand containing a few bands of dark grey clay up to 3' thick. The upper part of the deposit is composed of black clay containing bands of dark grey to black fine-grained sand from 3' to 20' thick. These sands and clays underlie grey billy, and the total thickness of the channel filling is about 280'. The sediments in both valleys are considered to have been deposited in the same lake system, which was later overrun by basalt or filled with basaltic breccia.

Wayne K. Harris of the South Australian Department of Mines has examined cores for spores and pollen from the buried channel adjacent to Wilmot Damsite and from the Basalt Creek Valley. His results are to be incorporated in a paper on Tasmanian Tertiary microfloras, but he has supplied the following personal communication. Drill Hole 4578 at the Wilmot Damsite failed to yield any spores or pollen. In the core from Drill Hole 4574, from the Basalt Creek Valley, 87' of basaltic breccia overlie 38' of indurated carbonaceous clay, and well preserved assemblages were obtained from the top 13', but the remainder of the deposit was barren. Good assemblages were obtained from near the breccia boundary and fragments of breccia appear in the clay indicating a close relationship in time. The assemblages are similar to those in

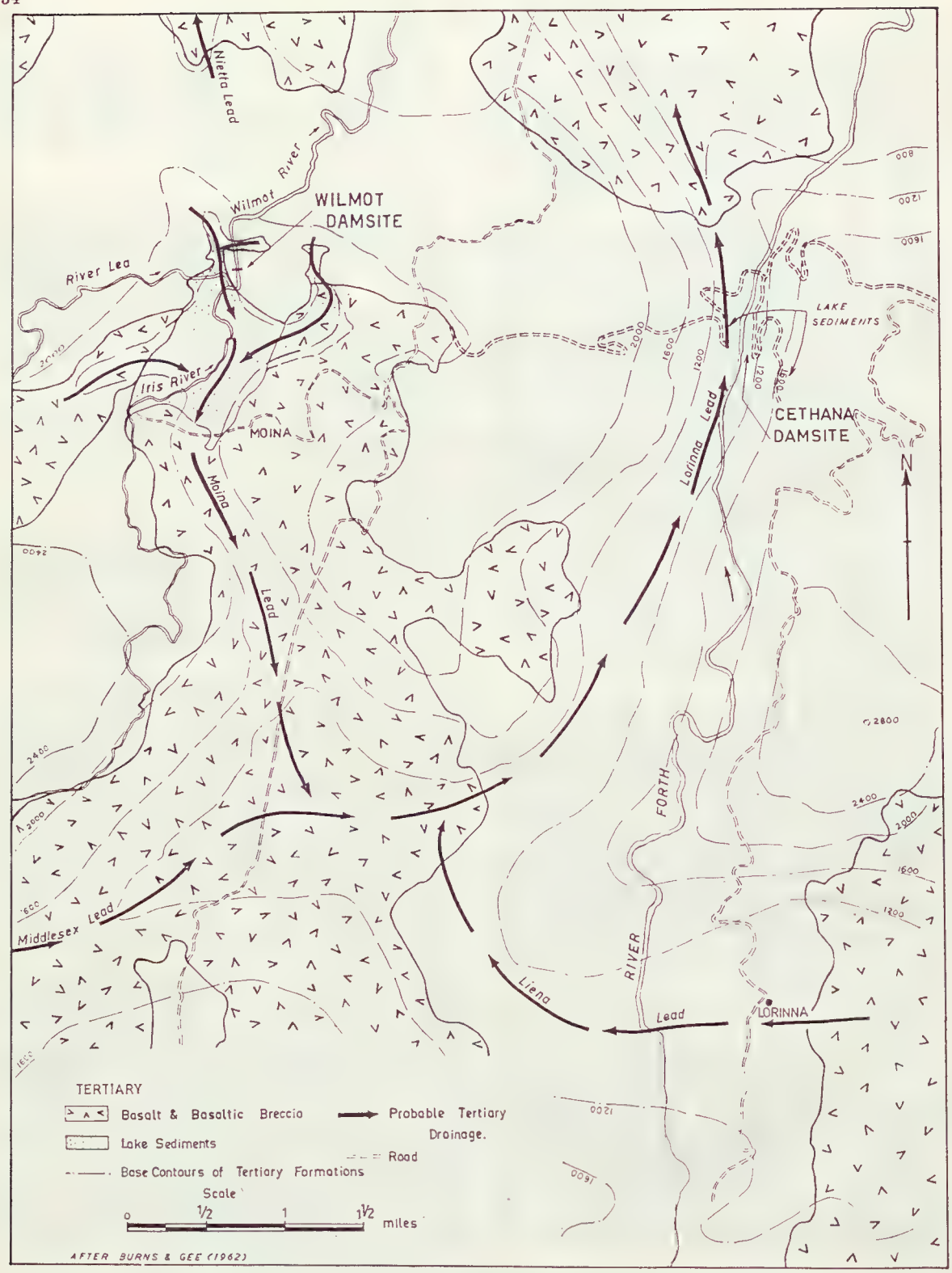

FIGURE 2.—Probable Tertiary Deep Lead Systems in the Moina-Cethana Area.

the Fossil Bluff Sandstone of N.W. Tasmania and Harris refers them to the Lower Miocene.

Bell Creek and its tributaries Mosquito, Poverty and Basalt Creeks were the site of a small alluvial gold field around 1900, and it is estimated (Twelvetrees, 1913) that some 4,000 ozs. of gold were won. The gold was obtained from alluvial gravels that bottomed in part on limestone and slate. Frequently the gold was obtained from immediately above a black clay pug, which the present writer considers to be part of the Tertiary sequence. The source of the gold was not found, but the gold probably originated close by to the north in the Ordovician sandstones and conglomerates on the southern flank of Bell Mount. As Twelvetrees pointed out it is unlikely to have come from the south for in this case it would be mixed with tin and wolfram ore from the Moina Area. The gold bearing gravels were probably reworked gravels of the Tertiary Drainage System.

Grey Billy

Grey billy caps prominent terraces on both sides of the Iris River and occurs as isolated remnants along the banks of the Lea River and along the buried channel west of Wilmot Damsite.

Grey billy occurs as blocks of siliceous conglomerate up to 15′ square on the Iris River Terrace (Plate 2, Figures 1 & 2). The conglomerates contain bands of sub-horizontal and cross-bedded, fine to coarse-grained siliceous sandstone, and these rock types resemble the Ordovician Roland Conglomerate. The conglomeratic grey billy is composed of rounded pebbles, cobbles and boulders of pink and white quartzite and white quartz, together with sub-angular to sub-rounded grains of quartz and feldspar set in a siliceous cement of chalcedony and/or quartz. The boulders are only sparsely jointed and quartz veins are absent. Under the microscope the quartz grains show expansion of the borders or diffuse borders with undulose extinction as a result of recrystallization. The framework varies from closed to open and the chalcedonic cement ranges from 5% to 25%. The fine-grained grey billy is composed of about 80% quartz grains and some grains of feldspar, with an average grainsize of 0.3 mm. 15% iron ore and 5% chalcedony. The framework varies from open to closed, and the cement is formed of chalcedony and recrystallized quartz. The quartz grains commonly contain inclusions of black opaque material which has been overgrown by optically continuous quartz. A description of some slides of the grey billy by Dr. Germaine A. Joplin is given as an appendix.

Under the microscope the conglomeratic and fine-grained grey billies can generally be distinguished from Roland Conglomerate rocks by the presence of chalcedonic cement and by the absence of mineralization and quartz veins. At Cethana Damsite a typical Roland Conglomerate is composed of sub-rounded to rounded quartzite and quartz pebbles and cobbles cemented by a fine-grained quartzose cement that is often accompanied by hematite. Mineralization is common throughout and patches are rich in pyrite, hematite, chlorite, siderite, arsenopyrite and tourmaline. Clay minerals occasionally are present and quartz veins are abundant.

The blocks of grey billy on the Iris River Terraces (Plate 2, Figures 1 & 2) are shown as landslide debris on the Department of Mines Sheffield Geological Sheet, and were thus presumably mistaken for boulders of Roland Conglomerate. The sub-horizontal attitude of the bedding of individual blocks clearly indicates that they are not the product of slope movement or ice transport, and the presence of chalcedony as the cementing agent, the lack of jointing, and the absence of quartz veins suggest silicification in place. The material silicified was apparently the upper surface of the Tertiary lake deposit; an aggraded gravel and sand piedmont plain.

The grey billy found along the buried channel (Plate 2, Figures 3 & 4) is more readily recognised. It occurs in outcrops with a visible thickness of 20′ and up to 75′ by 50′ in area. It is a siliceous breccia composed of angular to sub-angular boulders, cobbles and pebbles of pink and white quartzite, tubicolar sandstone (Moina Sandstone) and quartzite conglomerate (Roland Conglomerate) together with quartz grains in an open chalcedonic matrix. It is obviously a silicified scree, younger than both the Roland Conglomerate and Moina Sandstone.

Basalt covers large areas within the Iris-Lea River Valley and it is thought that silification occurred at the base of the basalt. Occurrences in Australia for which such an origin has been postulated have been discussed by Waterhouse and Browne (1929), Raggatt (1938) and Williamson (1957). Waterhouse and Browne suggested that silicification was accomplished by siliceous solutions introduced by the basalt aided by the solvent action of heated pore water acting on silica already present in the sediments.. This hypothesis is favoured for the Wilmot occurrences.

Rawlings (in press) has recognised grey billy beneath basalt on the eastern slope of the Forth Valley near Lemonthyne Creek and below the basalt plateau ¾ mile north of the old Cethana Village. Some outcrops at both localities resemble Roland Conglomerate on casual inspection, but silicified scree was also found at Lemonthyne and silicified wood was found near Cethana. Drilling at the latter locality showed the presence of amygdales of agate and chalcedony in the basal basalt flows indicating that siliceous solutions accompanied some of the volcanic activity. Rawlings has examined a siliceous deposit on Cockatoo Road near Cethana that was tentatively interpreted as a Pleistocene tillite by Jennings (1958) and concludes that this is a Tertiary grey billy. He has also examined a siliceous breccia on Maggs Mount that was described by Spry (1958) as a Tertiary fluviatile breccia and concludes this also is a Tertiary grey billy. Thus it can be seen that grey billy is widespread in the Wilmot-Mersey-Forth area.

The problem of recognizing grey billy raises the question of whether mistakes in identification have been made in other areas. This question is pertinent to the distribution of Ordovician conglomerates, with which grey billy is easily confused, and to the extent of ice transport during the Pleistocene where this is based on the occurrence of large boulders of siliceous conglomerates, identified as Ordovician conglomerates, scattered over the landscape.

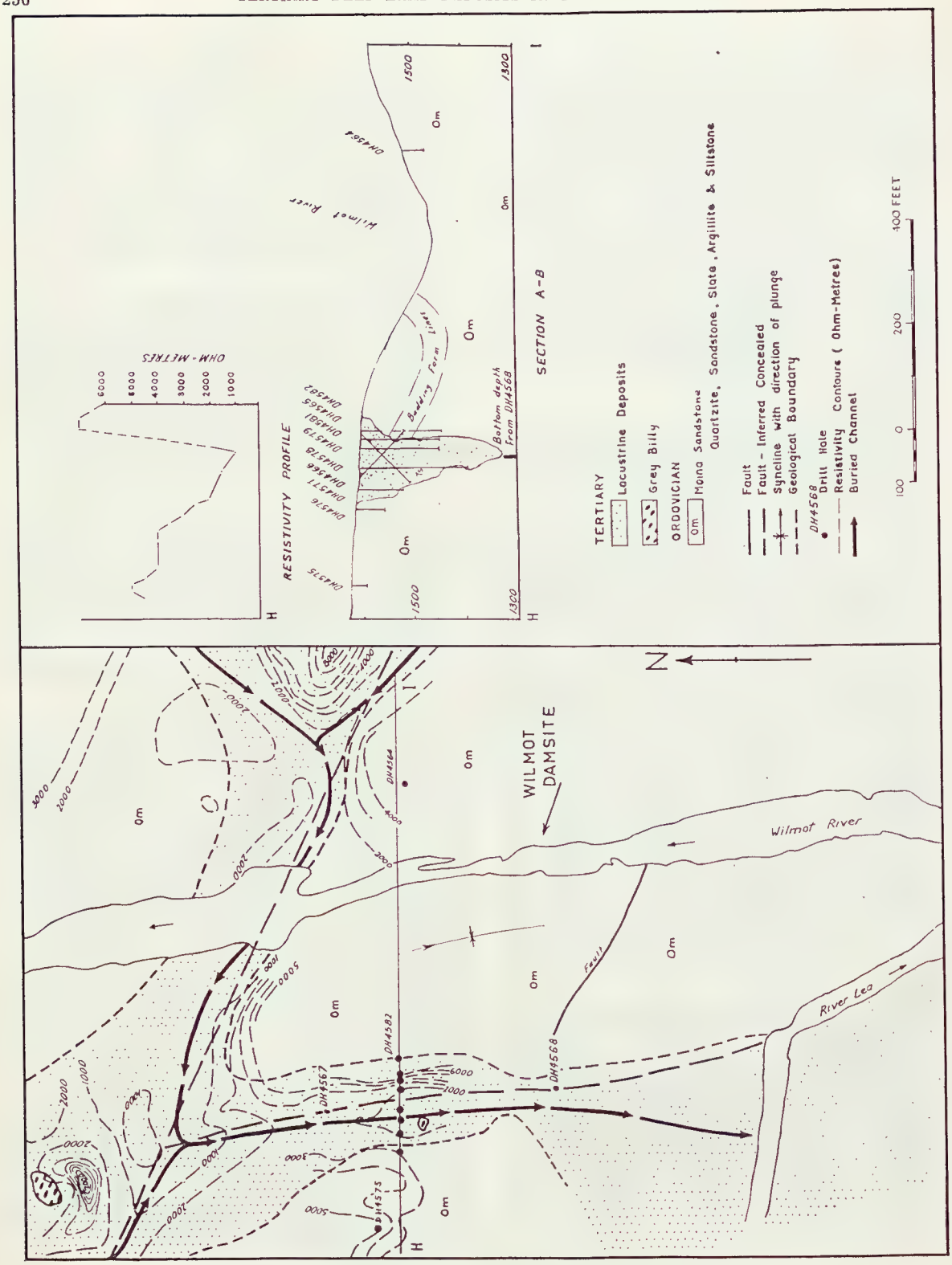

FIGURE 3.—Tertiary Deep Lead at Wilmot Damsite.

Basalt and Basaltic Breccia

Basalt and basaltic breccia blanket a large part of the Iris, Lea and Basalt Valleys. In the Basalt Valley Drill Hole 4571 passed through 139′ of weathered to partially weathered breccia, containing a number of bands of indurated black clay up to 11′ thick, before encountering the main lacustrine deposit. The rocks contain boulders of vesicular basalt up to 2′ diameter and fragments of volcanic glass in a basaltic matrix. The thick breccia sequence suggests the nearness of a centre of activity.

Petrographic Description of Grey Billy from the Moina Area by Dr. Germaine A. Joplin

The grey billy consists mainly of quartz grains and some grains of feldspar in a silica cement. Coarser types may also contain small pebbles of quartzite and some specimens contain an appreciable amount of a black opaque substance which may be graphite or an iron ore. This black material occurs in intergranular spaces and as a film around quartz and feldspar grains. Grains are rounded and are less commonly angular and range in size from about 6 mm. to less than 0.1 mm.

The silica cement may consist of quartz and/or chalcedony, the latter being present mainly in the finer grained parts of the rock, and in the quartzite pebbles of the coarser grained types. The finer grained rocks (e.g., Specimen 2) consists of small quartz and feldspar grains in a cryptocrystalline cement in which small spherules of radiating chalcedony may be distinguished. In some places a narrow rim of chalcedony surrounds the mineral grain.

Rocks containing a quartz cement are commonly coarser grained, because quartz grains have been overgrown by optically continuous quartz and thus enlarged. Where the original grain has been manteled with a film of black opaque material, this is enclosed by the quartz overgrowth.

ACKNOWLEDGMENTS.

The author is indebted to the Hydro-Electric Commission for permission to publish the information contained in this paper.

Grateful acknowledgment is made to G. E. A. Hale and G. Rawlings of the Commission for helpful discussion and to Dr. Germaine A. Joplin for examining grey billy specimens. The assistance of R. Preston in the preparation of figures is appreciated.

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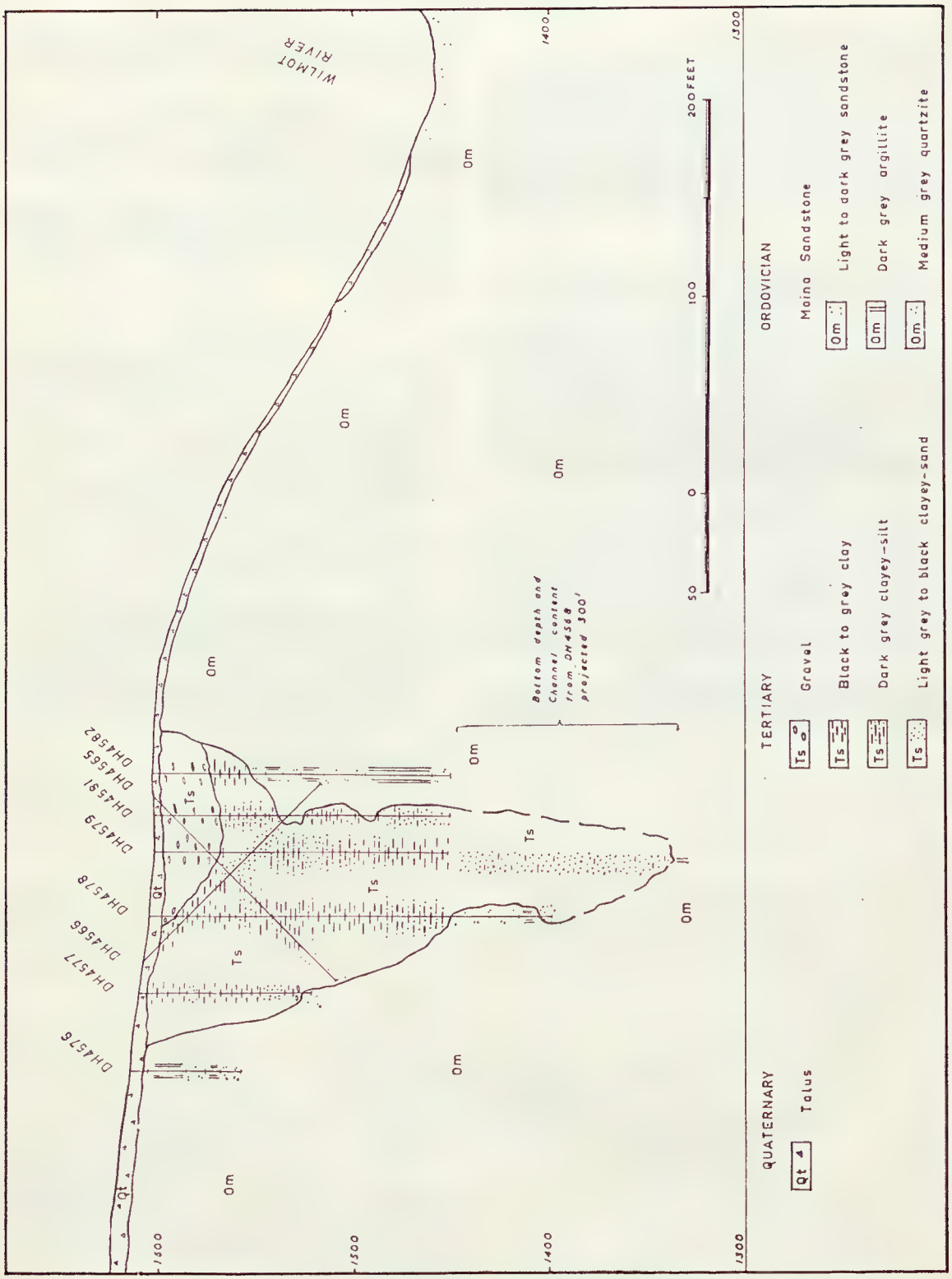

FIGURE 4.—Details of the Tertiary Deposits in the Deep Lead at Wilnot Damsite.

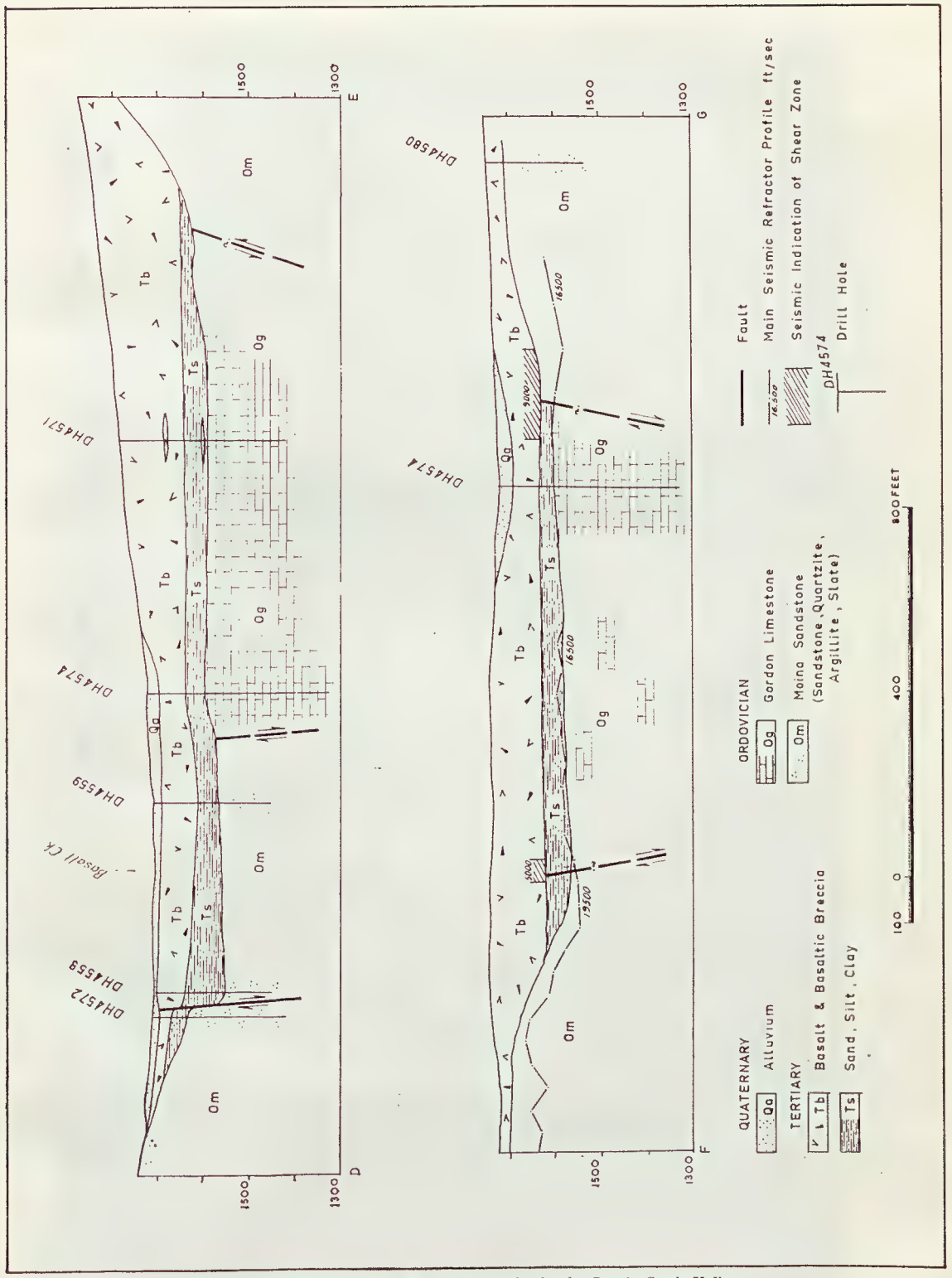

FIGURE 5.—Details of the Tertiary Deposits in the Basalt Creek Valley.

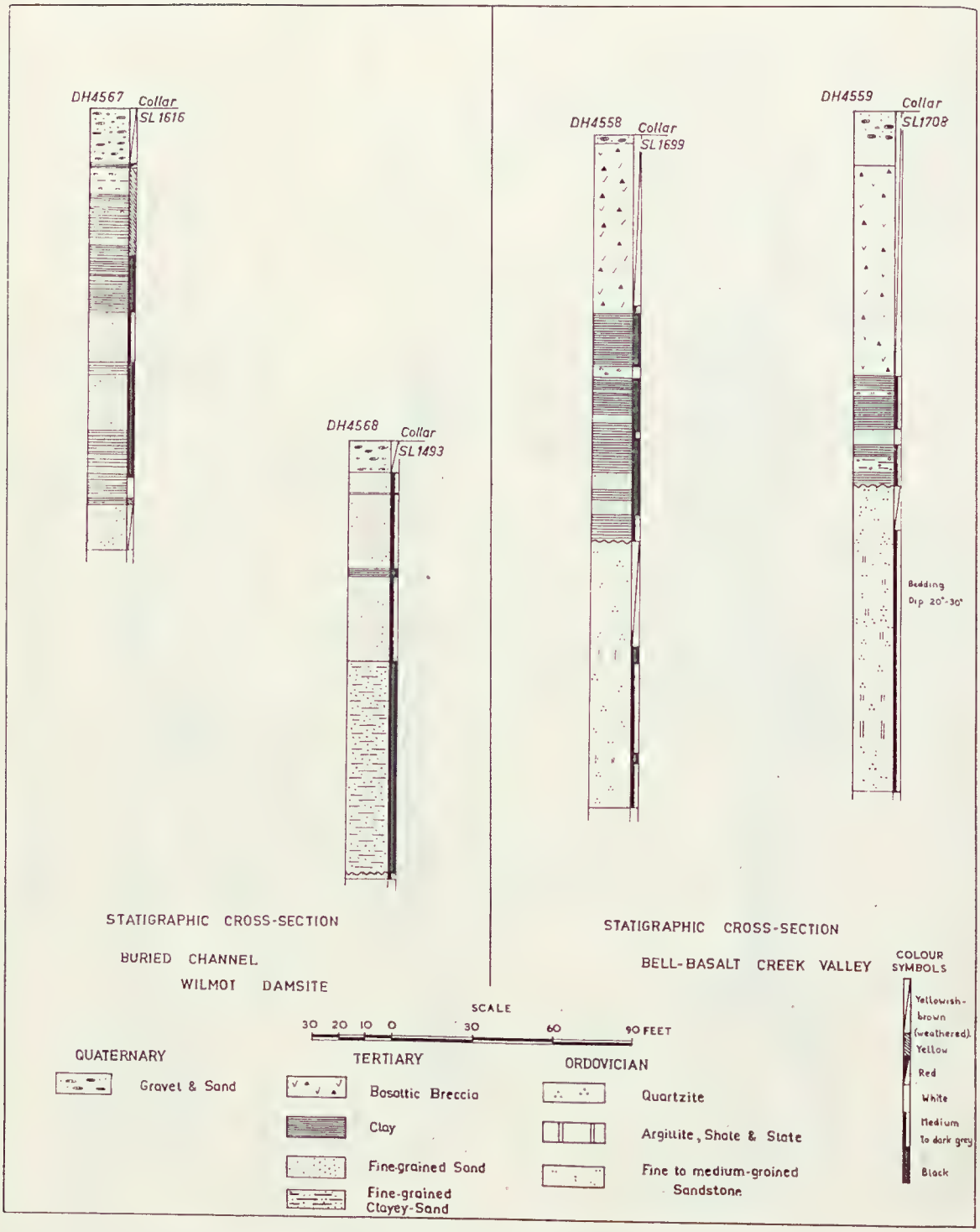

FIGURE 6.—Stratigraphic Cross-Sections.

PLATE I.—The left abutment of Wilmot Dam, showing a cyclical fold in Ordovician sandstone, quartzite and argillite. A Tertiary deep lead crosses the spur just above the abutment.

Plate II.

Figures 1 & 2.—Tertiary grey billy on the Iris River Terrace. A silicified gravel piedmont plain deposit showing sub-horizontal bedding.

Figures 3 & 4.—Tertiary grey billy above the deep lead adjacent to Wilmot Damsite. A silicified talus showing angular pebbles and boulders. Note the tubicolar sandstone boulder in Figure 4.

SOIL TYPE AND LAND USE, FLINDERS ISLAND

By

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ABSTRACT

Phases of land settlement and problems of land development are related to the C.S.I.R.O. soil survey of Flinders Island, 1957. The analysis is in terms of property ownership whether private or War Service Land Settlement, type of farming, associated vegetation, and difficulties of land improvement. It is concluded that knowledge of soil type has been essential for the spread of settlement, and that while further development is physically possible it may be precluded by the high costs of land development and the provision of adequate marketing facilities.

INTRODUCTION

Flinders Island, 513 square miles in area, lies in Bass Strait, at approximately 40°S and 148° E; with Cape Barren Island (172 sq. mls.) and Clarke Island (44 sq. mls.), and at least 40 other named small islands it belongs to the Furneaux Group. Owing to its maritime environment, Flinders Island has an equable climate (Koppen's Cfb), a winter rainfall maximum, a warm summer and mild winter. The average annual rainfall ranges from 28 to 31 inches, with possibly up to 34 inches in the Strzelecki Peaks in the southwest; the rainfall variability is 20.75% (from rainfall data for Pats River over 19 years). Strong westerly winds are common and frosts are rare.

PHASES OF SETTLEMENT

Apart from occasional visits by sealers and whalers prior to 1830, and the government settlement for the remnant of the Tasmanian aborigines between 1831-1847, "The Great Island of Furneaux" has seen three main phases of occupation and land development: (1) From 1847 the Island was leased as a whole for grazing, and although opened for selection in 1888, progress was very slow and mainly restricted to the central west coast. The *Crown Lands Guide*, 1885 described Flinders Island as "very rough and rocky, and little adapted for agriculture. The coarse native grass supports a few cattle, and on some of the smaller islands a few sheep are kept". Irregular shipping and lack of roads were further impediments. By 1896, there were 34 property owners on Flinders Island, including nineteen "graziers", nine "farmers" and four "mariners". (Witton, 1896). (2) About 1903 development was initiated in the south east, and in 1911 a boom in land speculation took place, similar to that on King Island (another Tasmanian island in Bass Strait). According to the official guide in 1912, there were " . . . considerable areas of good land in patches of a few hundred acres around the eastern and central portions of the Island . . . These areas consist of open cutting-grass tussock flats or mixed tussock and grass-tree land, having a dark sandy surface soil from 3 to 6 inches deep then 6 to 12 inches of sand, with a clay bottom 1 to 2 feet from the surface. This class of land is partially submerged during the rainy season, and is completely dry for a few months in the Autumn. The value of this land will no doubt be demonstrated during the next year or two by the incoming selectors who have acquired considerable areas of similar country together with the apparently richer lagoon lands."

Despite the optimism reflected here, settlement expanded only slowly, and fencing, clearing and actual utilisation lagged behind selection, particularly because of the capital cost of clearing and draining sufficiently large tracts.

(3) In 1947 a Joint Committee of both Tasmanian Houses of Parliament was appointed to examine communication facilities and the Island's potential for war service land settlement. It was concluded that Flinders Island was "admirably suited" for land settlement purposes, and it was recommended that "immediate steps be taken to provide sufficient farms for applicants desirous of settling on the Island". The phase of slow selection, with the recognition of potential in the east and Nelson's Lagoon area, thus drew to a close with increasing agitation for a share in the Commonwealth Closer Settlement Board's development projects. Phase three commenced with the initiation of land development by the Agricultural Bank of Tasmania in 1952 as part of the Closer Settlement Board's War Service Land Settlement Scheme; private development also occurred but was mainly confined to a small area in the south and south east.

SOILS AND LAND USE

A detailed soil survey of Flinders Island was published by the C.S.I.R.O. in 1957, with soil associations being mapped at a scale of 1:31,680; eleven soil series and one soil complex were differentiated and named. For convenience of reference, data from Table 5 in the C.S.I.R.O. Report (Dimmock, 1957) are retabulated here as Appendix I, with further comments on land use or cover, and location. Dimmock concluded, in summary, that: "The soils of the mountains [up to 2,500 ft.] and foothills are skeletal and residual soils, some highly leached and very old, on granite and quartzite. On the east and south coastal plain, there are deep acid sands (podzols and ground-water podzols), deep slightly calcareous sands with weak profile development, highly organic soils, shallow calcareous soils, and minor extents of clayey soils. The west coastal plain soils are mainly podzolic on

granitic detrital material, with some deep siliceous sands. The calcareous dunes are of two ages, the older having terra rossa soils, and the younger slightly leached shell sand". There is also a small area of fine-textured soil or basalt.

Table I indicates the distribution of all properties on the Island by seven soil groupings (classified geomorphically except for the complex category). Figure 1 summarises the locational relationships.

TABLE 1.

Property Distribution by Soil Group.

Major Soil Grouping.	*% total properties*		*% total Island area*
	Private	*Bank*	
Mountains	0.5	....	9.2
Foothills	12.5	11.1	29.1
East & South Coastal Plain	20.8	15.3	47.2
West Coastal Plain	10.6	....	4.5
Calcareous Dunes	15.7	....	9.4
Basalt flows	3.2	....	0.6
Complex grouping	8.8	1.9	....
Total	71.6	28.3	100

Private properties are inflated by the inclusion of undeveloped and/or ungrazed blocks; 46% of the 114 properties currently grazed are privately owned, 54% have been developed under the War Service Land Settlement Scheme. Clearly there is no simple relationship between the location of properties and the already dominant soil groups. The concentration of Bank properties on the east and south coastal plain historically reflects the avoidance of these associations because of the dune-lagoon complex and yacca scrub, together necessitating considerable expense in clearing and draining. Earlier private settlement was attracted to a greater variety of soil types, in particular the Bootjack and Wingaroo (east and south coastal plain), Ranga (calcareous dunes), Quoin and Emita (Foothills) associations; the west coast and central foothills associations were favoured by proximity to the Whitemark port facilities during the first two phases of settlement and associated rough-grazing. As already indicated, the potential of the south-east (for example, the Bootjack association north of the port-township of Lady Barron) was recognised in speculation as early as 1911. The data of Table 1 are retabulated below to differentiate types of farming and alienated but ungrazed properties in each major soil group.

(i) The steep granitic outcrops and skeletal soils of the Carena (mountain) association, mainly in the southwest and central south of the Island, support only stunted vegetation and provide a Scenic Reserve and water catchments.

(ii) The five foothills associations are located mainly in the northwest and centre of the Island; there is a range in soil characteristics with residual podzolic and skeletal soils—some highly leached, loose rock debris, prominent hardpans (Quoin),

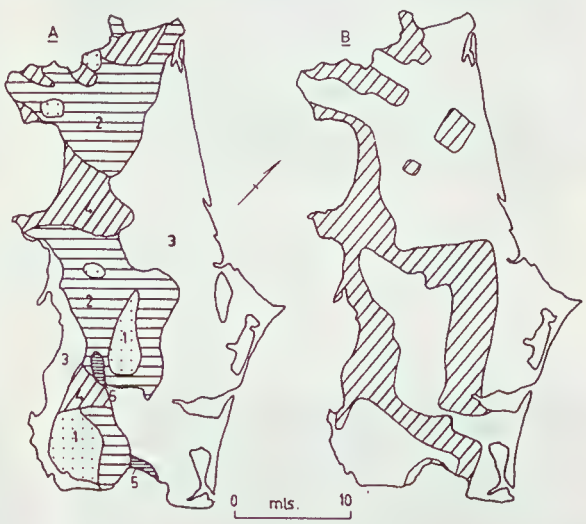

FIGURE 1.

MAP A.—Main soil groupings (Geomorphic units) after Dimmock; 1.—Mountains. 2.—Foothills. 3.—Coastal plains. 4.—Calcareous dunes. 5.—Basalt Flows.

MAP B.—Main cattle and sheep grazing area is shaded; the remainder is undergoing little or no pastoral utilisation at present.

TABLE 2.

Land Utilisation by Soil Group (% Total Properties).

Major Soil Grouping	*Dairy*	*Beef*	*Sheep*	*Mixed: Dairy, Beef, and/or Sheep.*	*Devd. not grazed.*	*Alienated not developed.*
Mountains	....	....	....	....	....	0.5
Foothills	0.9	1.9	9.7	4.1	4.6	2.3
E. & S. Coast	1.9	1.9	15.3	5.6	6.5	4.6
W. Coast	1.9	....	1.9	3.7	0.9	2.3
Calcareous dunes	0.5	1.9	1.9	8.8	3.2	0.5
Basalt Flows	....	....	0.5	1.8	....	....
Complex grouping	....	0.5	3.2	3.3	1.9	1.4
% Total	5.2	6.2	32.5	27.3	17.1	11.6

"melon-holey" micro-relief (Metta), and in the Liapota association there is deep sand with a well developed organic B horizon; vegetation is mainly sclerophyllous with peppermints (*E. tenuiramis*), bluegum (*E. globulus*), Sheoaks (*Casuarina distyla*), and yacca (*Xanthorrhoea australis*). Sheep grazing is particularly important with Agricultural Bank development of properties on Metta, Emita, and to a less extent the Quoin Associations; acidity, stoniness, restricted drainage, and low fertility are problems.

(iii) Seven associations make up the soils of the east and south coastal plains; teatree (*Leptospermum* and *Melaleuca* spp.), peppermint scrub and yacca predominate; soils include calcareous sands with weak profiles, deep gritty sands with either a well developed organic B horizon or clay subsoil, shell beds, highly organic lagoon soils, and fine-textured soils on alluvial flats; fossil dunes with lagoons limit utilisation of the Lackrana and Nala associations parallel to the east coast. Agricultural Bank development of sheep properties (with beef cattle as a supplementary income source) is concentrated on the Bootjack alluvial flats, the Wingaroo lagoon soils, and the shallow grey soils of the Memana association; Bank "buffer" blocks for agistment are found on the margins of the Nala stabilised dunes along the eastern side of the Furneaux Estate. The Agricultural Bank is currently clearing and carrying out initial development of the north central area of the Island on the undulating Petibela-Memana associations; salinity and inadequate drainage are the main problems here, and superphosphate, copper and zinc are essential for pasture development; on the better drained areas, strawberry clover, Yarloop and Clare subterranean clovers have given outstanding yields (Department of Agriculture, 1962) and emphasise the developmental potential of the area between "Wingaroo" and the northern limit of the Furneaux Estate for further grazing properties. The developed but ungrazed properties (see Table 2) are mainly within the Furneaux Estate, and a majority of the alienated but undeveloped properties are privately owned and situated on the Nala-Lackrana soils of the south east.

(iv) The three west coastal plain associations have developed as acid sands and grits on a marine bench. The main vegetation is teatree, low mixed scrub, with some yacca and sheoaks. Improved pasture is characteristic but increased drainage and trace element additions are necessary on this early-settled coastal strip. Dairying has been attracted both by the terrain and the location of the butter factory south of Whitemark.

(v) The Lughrata and Ranga associations (calcareous dunes), primarily in the north west and south west, include sands with little profile differentiation, and shallow brown to red-brown soils on limestone; the main surviving natural vegetation is teatree, and boobyalla (*Myoporum insulare*). Akalinity and erosion-potential minimise grazing on the Lughrata soils, while the free draining neutral Ranga soils have been extensively sown to improved pasture, with both sheep and beef cattle grazing; pasture and trace element trials continue to benefit production.

(vi) Improved pasture covers virtually all the three square miles of the Thule (Basalt flow) fine textured dark clay loam; gilgai microrelief and stoniness are minimal in limiting grazing or cultivation. The proximity to Whitemark and Lady Barron of the three main areas of this association favoured early clearing of the swamp teatree and the introduction of exotic pasture species for a variety of dairy-sheep-beef property combinations.

Taking account of the present extent of grazing properties, and obvious limits to further expansion (such as the Mountain associations and dune-lagoon complexes), land development can continue in two ways: (1) The area of Petibela-Memana-Nala soils north of the Furneaux Estate could be developed with the degree of capitalisation provided in current Agricultural Bank development; there has been no policy decision however as to whether the government should expand its Flinders Island project, and in fact, the future of the semi-developed (unoccupied) northern portion of the Furneaux Estate is in doubt. (2) Smaller areas with a variety of soil types, occur in a number of localities but of an acreage only attractive to settlers wishing to add to established properties; these could be privately developed but would not significantly increase the grazed acreage nor achieve a majority of private over Bank properties.

CONCLUSION AND ECONOMIC POSTSCRIPT

There is no doubt that granted a sufficient demand for grazing properties, the availability of finance for land development, and the provision of adequate transport and/or abattoir facilities to cater for a markedly increased turnoff, a further 12,000 to 15,000 acres could be developed on Flinders Island; a similar acreage, mainly on Quoin soils, could be developed on nearby Cape Barren Island, though the transport problem would be heightened here by the inadequate port facilities and absence of access roads.

The qualifying statements introduced in the above paragraph are, however, the critical factors. The physical capability of the soils on the Island is established, given highly capitalised drainage, clearing and long-term nutrient development. A majority of the physical problems of land development have been overcome, as discussed elsewhere (Pryor, 1967). The important questions now are: Would cost-benefit analysis validate the development of this geographically isolated area as compared with more accessible Tasmanian or mainland locations? Recognising that expanded production must be directed to Victoria rather than to the already saturated Tasmanian market, would the provision of adequate marketing facilities, shipping, better port handling and possibly an abattoir, guarantee the Island's integration into the Australian economy? (The Bureau of Agriculture in 1961 recommended the erection of an abattoir, while recognising that "as an isolated investment it will be uneconomic".) Finally, what measures can be adopted to ensure continued viability if economic and other pressures were to extinguish land development or transport subsidies? The physical questions have been answered, but the economic questions remain.

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APPENDIX I

SOIL ASSOCIATIONS AND LAND USE, FLINDERS ISLAND

Geomorphic Unit	*Soil Association*	*General description of* (i) geomorphology (ii) soils	*General landuse or landcover*	*General location*	*Area sq. mls.*
Mountains ..	Carena	(i) Granite, steep slopes, elevations to 2,500 ft. (ii) Mainly bare, a few skeletal soils	Scenic reserve, water catchments stunted vegetation	SW, centre, and scattered patches	47
Foothills ..	Lenna	(i) Quartzite and slate to 1,500 ft., some steep (ii) Residual podzolic and skeletal soils, loose rock debris	Limited pasture; catchments, timber (sclerophyllous)	Central W, sth. coast	27
	Quoin	(i) Granite, mature dissection (ii) Strongly weathered, highly leached, some prominent hardpans	NW little used; centre Ag. Bank impr. pasture	NW, centre SW	73
	Metta	(i) Granite and quartzite margins, valley floors of Quoin and Lenna hill soils (ii) "melon-holey" micro-relief	Ag. Bank impr. pasture	Centre, mt. margins	18
	Emita	(i) Granite hills, tors common (ii) Podzolic, high % relatively unweathered primary minerals (cf. Quoin)	Emita impr. pasture; yacca, timber	Emita, central W	23
	Liapota	(i) Sand over granite to 600 ft. (ii) Deep sand, well developed organic B horiz.	Reverted bracken	NE, NW	8
Coastal Plains: (a) East ..	Lackrana	(i) Beach ridges, fossil dunes with lagoons (ii) Slightly calcareous sands, weak profiles	Dunes, low scrub	All E coast, Whitemark	31
	Nala	(i) Stabilised dunes, lagoons; to 20 ft. (ii) Deep gritty sands, well dev. organic B horiz.	Dense scrub, margins impr. pasture	E inland belt	98
	Petibela	(i) Undulating sand rises and alluvium strips, 15 to 100 ft. (ii) Gritty sands with clay subsoils	Yacca scrub; Ag. Bank clearing and some impr. pasture	N central	29
	Memana	(i) Broad flats, formerly coastal lagoons, 25-80 ft. (ii) Shallow grey soils over hard calcareous horiz. of secondary carbonate with some shells	Yacca scrub; Ag. Bank clearing, limited impr. pasture to date	N central	29
	Wingaroo	(i) Do. Memana; younger, sea level to 20 ft. (ii) Highly organic lagoon soils over loose sand and shell beds	Impr. pasture; Ag. Bank on S central after drainage	S central, NE	24
	Bootjack	(i) Broad alluvial flats, low sandy rises, gentle fall to coast, 100 to c.20 ft. (ii) Fine textured soils on flats, sandy soils on subordinate low rises	Impr. pasture; Ag. Bank on centre	Sth., Centre	20

APPENDIX I—*contd.*

SOIL ASSOCIATIONS AND LAND USE, FLINDERS ISLAND

Geomorphic Unit	*Soil Association*	*General description of* (i) geomorphology (ii) soils	*General landuse or landcover*	*General location*	*Area sq. mls.*
Coastal plains: East—*contd.*	Altmoor	(i) E-W sand dunes on a plain of Stratified unconsolidated marine sediments, 100-200 ft. (ii) Siliceous sands with organic B horizon rises, very variable soils in troughs	Impr. pasture except on shallow sand	Central Sth.	11
(*b*) West ..	Whitemark	(i) Marine bench av. 15 ft. above s.l. (ii) Deep sands and grits, shallow grey soils over limestone or clay	Impr. pasture	SW inland belt	10
	Loccota	(i) Continues marine bench (Whitemark), flat granite and quartzite colluvium, some dunes (ii) Various angular grits and other soils on granite detritus	Impr. and rough pasture	SW coast	7
	Blue Rocks	(i) Do. Loccota; remnant of higher and older bench, at c.30 ft. (ii) Various soils, incl. deep sands, sandy shingle, and soils of Ranga Assocn.	Most in pasture, some impr.	Central W coast	6
Calcareous Dunes	Lughrata	(i) Younger series; hairpin dunes of shell sand adjacent to coast; some sand blows over granite hills (ii) V. calcareous sands, little profile differentiation except organic matter	Minimal natural pasture; shrubs (eg. manuka) and reeds	NW and SW coasts	13
	Ranga	(i) Older series; longitudinal ridges on granite and quartzite to 500 ft.; dune limestone, sink-holes and caves (ii) Shallow brown to red-brown soils on limestone	Impr. pasture extensive	2 areas W inland	36
Basalt Flows:	Thule	(i) Small plateau at 400 ft.; small, widely scattered lower outcrops (ii) Fine textured dark clay loam	Impr. pasture extensive	Sth. coast, Thule	3
Laterite ..	..	9 small occurrences (not mapped separately by Dimmock); composed of pisolitic mat. or ferruginous sandstones or grits	..	widely scattered	..
A	A	B	C		A

Sources: A —Dimmock, G. M., *op.cit., passim.*
B —Dimmock and Field work.
C —Field work.

SUB-BASALTIC SEDIMENTS AND METASEDIMENTS OF THE MERSEY-FORTH AREA

By

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Hydro-Electric Commission, Tasmania.

(With one text figure and three plates.)

ABSTRACT

Lacustrine sediments and silicified river gravels, slope deposits, *in situ* weathered material and joint fillings of Tertiary age in the Mersey-Forth area are described. An assessment is made of Tertiary drainage directions and the degree of post-basalt downcutting.

INTRODUCTION

Investigations for the Mersey-Forth Power Development Scheme have shown that Tertiary sub-basaltic sediments and metasediments are widespread. Evidence has been found for the silicification of river gravels, slope deposits, *in situ* weathered material and joint fillings. Such silicified deposits and the lacustrine sediments permit the elucidation of the Tertiary drainage pattern and the extent of post-Tertiary basalt downcutting in the Forth River.

Brief mention is made by David (1950) of Tertiary basalt covered gravels between 400′ and 500′ above the level of the present Forth River. He writes generally of gravels, sands, clays with lignite, locally cemented and basalt capped, being spread over the country at altitudes of 200′ to 500′ generally on the interfluve ridges. Such a description could well be applied to some of the basins of Tertiary sediments in the area under consideration.

LACUSTRINE SEDIMENTS

Sub-basaltic and intra-basaltic lacustrine sediments are common in the Mersey-Forth area and typically range from stiff black clays to fine grained sands as seen in drill holes on the Wilmot Tunnel Line (Paterson 1967). Lacustrine sediments exposed on the new Wilmot Road at 560′ S.L. (Fig. 1, locality 1) are composed of grey-brown sands and silts overlying river gravels and grading up into thick white clays (Plate I, a). Boulders of silicified scree cap the sequence. Similar lacustrine sediments with well preserved plant remains and thin seams of carbonaceous material are exposed on the opposite bank of the Forth River on the H.E.C. Works Area Access Road at 909′ S.L. (Fig. 1 locality 2). Both outcrops show dips towards the river and it seems likely that the Tertiary River Forth was dammed by faulting downstream of Cethana Damsite or possibly by a basalt flow.

SUB-BASALTIC METASEDIMENTS (GREY BILLY)

More widespread than the Tertiary lacustrine sediments are the silicified deposits which lie beneath the basalt, close to the margins of the present basalt outcrop or in widely dispersed areas showing the former location of basalt flows. Their diagnostic features have been described by Paterson (1967) from the Moina area and they can be recognized by the same characteristics further afield. Several authors (Spry 1958, Jennings 1958) have described silicified deposits but have not recognized their genetic affinity to the local basalt flows. As investigations in the Mersey-Forth area have proceeded it has been realised that such silicified deposits, the grey billy of David (1950) and other authors, are more widespread than formerly supposed and it is expected that further detailed work will provide more evidence of their existence.

The best example of *in situ* grey billy is found on Emu Plains (Fig. 1, locality 3) close to the margin of the basalt outcrop where silicified scree deposits or *in situ* weathered material lie as a mantle over Precambrian quartzite bedrock (Plate I, b). The grey billy is composed of angular to sub-angular pebbles and occasionally cobbles of grey quartzite of local origin cemented by a grey saccharoidal siliceous matrix. The siliceous cement is extremely hard and has allowed the grey billy to be preserved as a resistant capping to the bedrock. An extensive search has revealed the presence of boulders of similar material around the margins of the basalt although often the constituents include many well-rounded quartz and quartzite pebbles.

To the north of Lemonthyme Creek and close to the Dove schist/Fisher quartzite junction (Fig. 1, locality 4) large blocks of grey billy are found between the basalt outcrop and the Forth River. They are up to 5′ in diameter and are composed of angular to well rounded pebbles and cobbles of grey quartzite or schistose quartzite set in a siliceous matrix. It is considered that their present location may be due to transport by ice flowing down Lemonthyme Creek (Paterson 1965).

Numerous blocks of grey billy are found along the new Wilmot Road (Fig. 1, localities 5 and 6) which

runs from the Forth River to the Cradle Mountain Road over scree slopes of Moina Sandstone quartzite. The blocks are up to 15′ in diameter (Plate II, a) and are generally composed of silicified quartzite scree although some rounded material may also be present. The grey billy rocks, some of which may not be *in situ*, have a dip component towards the Forth valley.

In the area a mile north of Cethana Village (Fig. 1, locality 7), where the basalt overlies Cambrian bedrock, numerous boulders and cobbles both of quartzite conglomerate and silicified wood are found. No *in situ* exposures have been seen but drilling in the area showed the presence of amygdales of agate and chalcedony in the basal flows.

Jennings (1958) mapped ' conglomerate ' on the north-east face of Cockatoo Ridge (Fig. 1, locality 8; Plate II, b) in the Round Mount area. It outcrops in a face 15′-20′ high and is composed of angular to rounded pebbles, cobbles and boulders of grey-pink quartz, quartzite, grit and conglomerate set in a granular siliceous matrix. It is structureless and boulders of Roland Conglomerate and Moina Sandstone up to 2′ diameter may be recognised. Jennings considers this is possibly a relic of a Permian till but due to its low elevation has tentatively interpreted it as being of Pleistocene age. The deposit bears all the characteristics of a sub-basaltic metasediment and is considered to be the result of silicification of river gravels and slope deposits by basalt flowing from Oliver Hill down Claude Creek valley towards the Forth River. Jennings' ' fluvioglacial deposits ' lower on the same hillside are also considered to have the same origin although these are confused with recent slope deposits and possible outcrops of Roland Conglomerate.

Further up Cockatoo Road large blocks of Moina Sandstone are found between the road and Claude Creek (Fig. 1, locality 9). Some of these are believed to be *in situ* but many have tumbled from a terrace below the road. The upper surfaces and open joints of many of the *in situ* blocks show veneers or fillings of medium grained grey quartzite different in texture from the quartzite bedrock (Plate 3). The quartzite mantling the blocks is occasionally seen to run down into the open joints. It is considered that the quartzite mantling the blocks and filling the open joints has resulted from silicification by the basalt of sandy scree overlying the bedrock and infilling the major open joints.

Spry (1958) mapped ' fluviatile breccia ' on the northern end of Magg's Mount at 2415′ S.L. (Fig. 1, locality 10). It occurs at the junction between the Precambrian quartzite and the Tertiary basalt and is composed of angular to well rounded pebbles and cobbles of light grey quartzite set in a sandy or dense siliceous matrix. It is poorly sorted. Although this out-crop is not well exposed it is considered to be a sub-basaltic metasediment similar to those described previously.

ORIGIN OF THE GREY BILLY

The occurrences of grey billy described in this paper bear out the hypothesis that silification occurred mainly as the result of silica-bearing solutions being introduced by the basalt and aided by the solvent action of heated pore water acting on silica already present in the sediments (Waterhouse and Browne), 1929; Raggatt, 1938). The presence of siliceous amygdales in the basal basalt flows near Cethana village and the general absence of grey billy except where the sediments are predominantly siliceous seem to support the hypothesis. Dr. G. A. Joplin has recognised a chalcedonic cement as being characteristic of finer-grained grey billy deposits and a quartz cement as being characteristic of the coarser-grained deposits (Paterson, 1967). It is possible that the cement may be related to the presence or absence of silica-bearing solutions accompanying the basalt but further investigation of grey billies in relation to their parent basalts is needed before any definite connection can be ascertained. Certainly permeability of the sediments must have been a strong factor in their susceptibility to silicification. G. Urquhart (pers. comm.) has mapped similar grey billies in the Savage River area where metasediments are intercalated with unsilicified deposits.

The original sediments seem to be variable and often heterogeneous in character. The silicified well sorted sands and gravels of the Moina area contrast strongly with the silicified scree deposits of Emu Plains and the new Wilmot Road. However the Lemonthyme, Magg's Mount and Cockatoo Ridge grey billies are characterized by the appearance of markedly angular and well rounded material in the same deposit. It is considered that much of the angular material must have been carried down the scree slopes into the valley bottoms by the flow of the basalt into the drainage channels.

CONCLUSIONS

Recognition of silicified sub-basaltic sediments permits further elucidation of the Tertiary drainage pattern. Flows into the Cethana Damsite area were towards the ancestral Forth River, which occupied a similar course to that of the present day, and are shown by the presence of grey billy outcrops along the new H.E.C. Wilmot Road at successively lower levels proceeding down to the edge of the present Forth Valley. The level of the river gravels underlying the lacustrine sediments to the west of the Forth River corresponds well with the level of the upper valley in the valley-in-valley structure of the Cethana Damsite area. This suggests that some 170′ of downcutting has occurred in pre-Tertiary rocks since the deposition of the lake sediments. Well compacted river gravels of probable Tertiary age which are found down to at least 710′ S.L. upstream of Cethana Damsite support this view.

Tertiary pre-basaltic relief in the Mersey-Forth area was probably of the order of 1000′ with deeply incised valleys separated by interfluves whose surfaces showed prominent though not rugged topography. The incision of the valleys is exemplified by the steep-sided buried channel recently located at Wilmot Damsite (Paterson 1967).

ACKNOWLEDGMENTS

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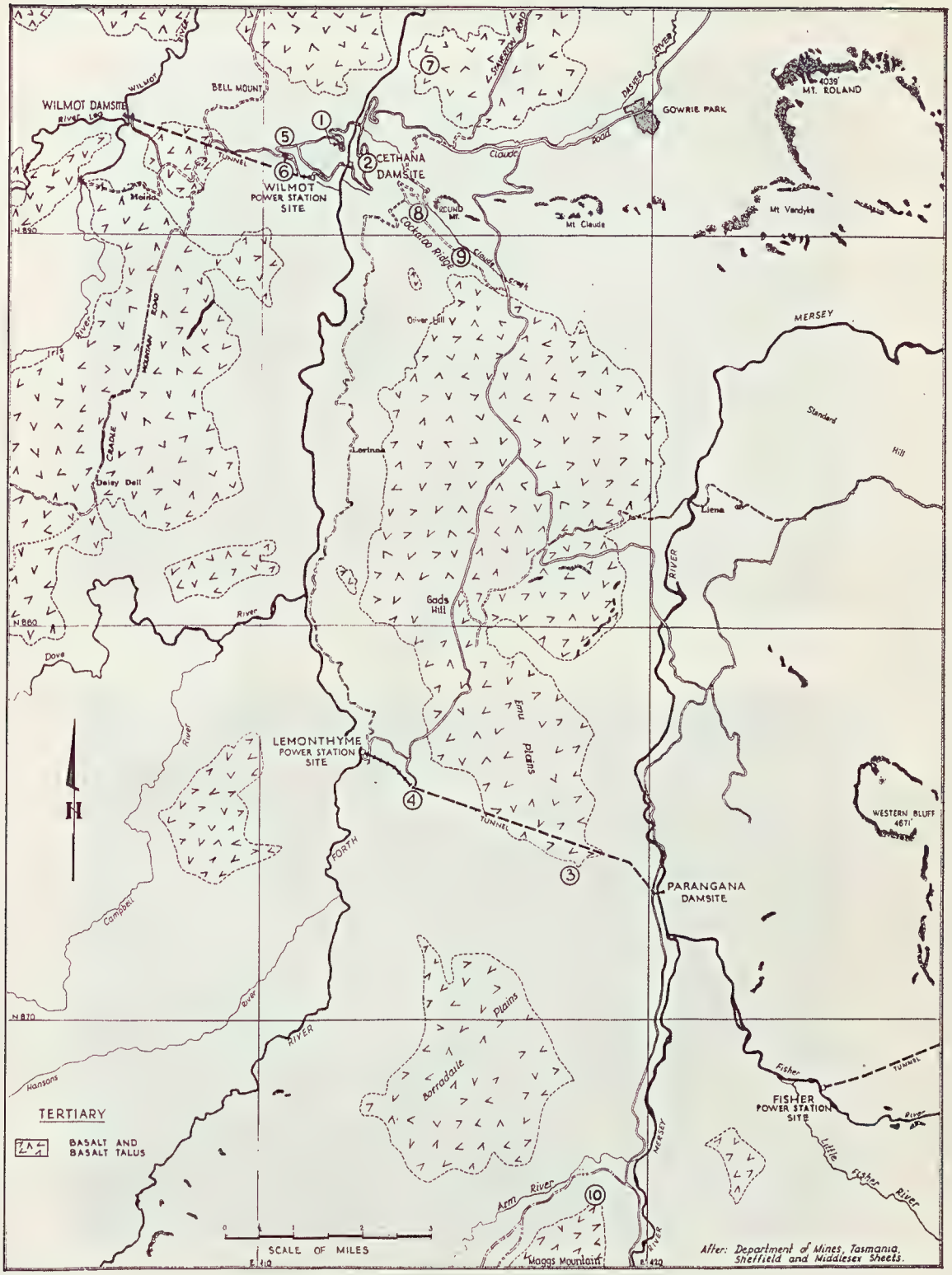

FIG. 1.—Location of Sub-basaltic Sediments and Metasediments.

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Plate I (a)—Tertiary lacustrine sediments overlying river gravels. Strong leaching shown by banding. New Wilmot Road. (Fig. 1, Locality 1).

Plate I (b)—Grey billy mantling Precambrian quartzite. Emu Plains (Fig. 1, Locality 3).

Plate II (a)—Silicified quartzite scree. New Wilmot Road. (Fig. 1, Locality 6).

Plate II (b)—Silicified river gravels and/or slope deposits. (Fig. 1, Locality 8).

Plate III.—Grey billy filling joint in Ordovician quartzite.

THE ORIGIN OF DEFORMED CONGLOMERATE AND PSEUDO DEFORMED CONGLOMERATE; WITH PARTICULAR REFERENCE TO THE ROCKS AT GOAT ISLAND, TASMANIA

By

A. Spry[1] and K. Burns[2]

(With two plates and one text figure.)

ABSTRACT

Rocks produced by the deformation of conglomeratic sediments strongly resemble pseudo-deformed conglomerates in which tectonic disruption of beds, veins and pebbles produce pebble-like bodies.

The Goat Island Conglomerate is a tectonic mélange containing numerous tectonically formed fragments but is dominantly a metaconglomerate.

INTRODUCTION

Foliated rocks containing flat or elongate fragments have been widely recognized as deformed conglomerates (stretched-pebble conglomerates) but it is not generally appreciated that rocks of different origin (pseudo deformed conglomerates) can resemble them very closely.

A deformed conglomerate is a rock of conglomeratic appearance in which the fragments are strongly elongate or flat with a preferred orientation. It is a deformed epiclastic rudite.

A pseudo deformed conglomerate contains flat, elongate or somewhat irregularly shaped fragments which have been formed by tectonic or metamorphic processes. It is generally foliated or lineated and is a cataclastic rudite.

Rocks at Goat Island, near Ulverstone on the central north coast of Tasmania, were considered by Twelvetrees (1903), Dunn (1926), David (1932) and others to be deformed conglomerates. The first suggestion of the pseudo-conglomerate nature of some of the rocks appears to have been made by Professor E. S. Hills on an A.N.Z.A.A.S. excursion in 1949.

The geological environment has been given by Burns (1964) and a detailed discussion of the structure will be presented elsewhere. Both deformed conglomerates and pseudo deformed conglomerates are present. The "Goat Island conglomerate" is a tectonic mélange (Greenly, 1919) derived by the deformation, under low-grade regional metamorphic conditions, of a group of conglomerates, quartzites and phyllites.

A brief review of the nature and origin of metamorphic conglomeratic rocks is presented as a background to the derivation of possible criteria for distinguishing between the various types.

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DEFORMED CONGLOMERATES

There are claims in the literature on stretched-pebble conglomerates that various ellipsoidal bodies are sedimentary pebbles which have been distorted, even though, in most cases, no evidence is given to establish that the objects were originally pebbles. It is difficult (Wilson, 1961, p. 517; Hills, 1963, p. 127), and indeed in some cases, impossible, to distinguish between true and pseudo deformed conglomerates and some authors seem to be content to accept a rock as a true deformed conglomerate solely on its appearance. One might, however, question whether an object looking like a "walking stick" with dimensions of 100:3:1 or like a plank (330 x 30 x 8 cms. Kvale, 1948, II, p. 31) or like sheets of cardboard of great size (Van Hise, 1904) are really deformed boulders.

Deformed conglomerates can be classified into a number of groups depending on the internal structure of the fragments which in turn reflects the mechanism of deformation.

I. *Sedimentary.*

Deformation of soft fragments in unconsolidated sediments of low strength takes place by intergranular movement; the deformation is commonly continuous and without fracture. The total amount of strain may be large.

II. *Tectonic.*

(1) Deformation of lithified conglomerate at shallow depths (e.g. of quartzite-conglomerate near faults) may cause small amounts of strain. Deformation is discontinuous, and takes place by shear along conjugate fractures. The sense and amount of movement on the fractures can be recognized by the displacement of the outer surface of the pebbles but the fractures are "healed".

(*a*) In the shallow *Beaverhead type* (Tanner, 1964) the *acute* bisectrix of the shears is parallel to the principle stress axis.

(*b*) Deformation at apparently greater confining pressure, but still at apparently shallow depth in the *Loch Lomond type* (Ramsay, 1964) produces conjugate fractures similar to the previous type except that the *obtuse* bisectrix of the shears is parallel to the maximum stress axis.

(2) Deformation of conglomerates during regional metamorphism of low to moderate grade may produce moderate amounts of strain by a continuous process involving recrystallization rather than fracture. The mechanism of deformation depends on the physical conditions and ranges from intergranular cataclasis and slip on one or more internal foliations (Goat Island type) to a kind of recrystallization-low (*Fetlar and Bygdin types;* Flinn, 1962; Oftedahl, 1948).

(3) At the high temperatures and pressures of high-grade regional or plutonic metamorphism, conglomerates undergo large amounts of strain by some kind of viscous flow, (*New Hampshire type;* Walton *et al,* 1964).

Lithology.

Pebbles of quartz and quartzite are most common but the occurrence of granite (Elwell, 1955), gneiss (Lawson, 1913), slate (Paige, 1924), limestone (Park and Cannon, 1943) and trachyte (Stockwell and Lord, 1939) as dominant pebbles has been recorded.

Pebbles in deformed conglomerates appear to be invariably surrounded by a matrix which may be siliceous, arkosic, greywacke or pelitic. The proportion of matrix ranges up to 40% (Billings, 1937), 50% (Gunning, 1941), even 80% (Brace, 1955). The matrix is schistose or mylonitic and has apparently undergone considerable movement.

The final shape of a pebble depends on its initial shape, size, physical properties, the total strain of the enclosing rock and the proportion of strain in the matrix. It is generally assumed that the original pebbles were near-spherical but the original shape has a profound influence on the shape after deformation. Variation in shape between closely spaced pebbles of the same composition is probably due to differences in original shape rather than to inhomogeneity of strain.

The amount of deformation of a pebble is related to its size because the larger pebbles in some conglomerates are less-deformed than the smaller (Gruner, 1941; Osberg, 1952; Elwell, 1955).

Mehnert (1938, p. 252) showed that quartzite pebbles were elongated to 10 times their least diameter whereas micaceous greywacke pebbles in the same rock were elongated 45 times. Work of Gunning (1941), Kvale (1948, II, p. 28) and Flinn (1956) showed that a given conglomerate, coarse acid-igneous pebbles are least deformed, quartzites are next, then greywackes, with pelitic pebbles undergoing greatest deformation.

The longest and mean axes of the pebbles are generally parallel to the foliation in the matrix (although this is not always the case) and the long axes are parallel giving a pronounced lineation.

Deformed conglomerates belong to a number of tectonic environments:

(1) The Beaverhead and Loch Lomond types with their fractured pebbles are related to steep faults.

(2) Some normal deformed conglomerates, (e.g. Bygdin type) occur in regions of alpine tectonics. It has been said that the elongation is related to movements parallel to large thrusts, and that deformation is greatest near the thrust (Goldschmidt, 1916; Oftedahl, 1948; Flinn, 1956, 1961; Kvale, 1946; 1948; Strand, 1945) but this is in doubt.

(3) Some normal deformed conglomerates are enclosed in strongly folded meta-sediments (commonly isoclinal with several episodes of folding) where the pebbles are generally elongate parallel to fold axes and other lineations (Stockwell and Lord, 1939; Cloos, 1946; Brace, 1955; Hobbs, 1962). However some examples have elongation "down-dip" or normal to the fold axes (Billings, 1954, p. 357-8; Paige, 1924; Osberg, 1952).

(4) Little is known of the tectonic environment of the deformed conglomerates associated with gneisses and granulites.

The mechanism by which near-spherical pebbles are changed to ellipsoids is not known but four kinds have been discussed:

1. The simplest case is that of a sphere which is converted to an ellipsoid by pure shear. The symmetry of the strain and of the rock is orthorhombic. This fits the example of Lawson (1913) and Osberg (1952) where the long and mean axes of the pebbles lie in a foliation and the pebble-axes are perpendicular to the fold-axes. It has not been regarded as compatible with the common case where the pebble axes are parallel to the fold axes. "Flattening" by slip along conjugate shears is dominant in the Loch Lomond and Beaverhead types and is important at Goat Island.

2. A sphere may be converted to an ellipsoid by simple shear along a single set of shear surfaces. The long axis of the ellipsoid is at an angle to the shear surfaces and the symmetry of the movement and of the rock is monoclinic. Oftedahl (1948) and others have regarded the foliation in the matrix as representing the surfaces of slip, but they are faced with the anomaly that the long and mean axes of the pebbles are parallel to the schistosity and not oblique. Oftedahl suggested that the simple shear was followed by rotation of the pebble into the schistosity but the pebbles are significantly different from the shape predicted by such a mechanism and no evidence was found of a slip surface in the pebbles. Brace (1955) suggested that the pebbles in the Vermont conglomerate could not have rotated because of the lack of disturbance of fine sedimentary lamination. Shear along a single set of surfaces has operated at Goat Island where some fragments are oblique to that matrix foliation which passes through them.

3. A sphere may be converted to a cylindrical shape by rolling, e.g. a ball of putty rolled between the hands takes on a cigar-shape (Hills, 1940; Elwell, 1955). Such an hypothesis allows correlation of pebble axes with the fold axes and with the fabric of the rocks, but pebbles such as Kvale's 100:3:1 "walking sticks" would require a great deal of rolling. The hypothesis is inadequate to account for the very flat pebbles which are common in deformed conglomerates.

4. Various complex combinations of "rolling and flattening" (Flinn, 1962) may be closer to the truth and many authors have considered a rather vague process of rock flow and viscous drag. This concept was recognized as long ago as 1862 when Scrope discussed the elongation of vesicular cavities in

lavas; Harker (1885) applied it to the deformation of fossils &c., in metamorphic rocks and Flinn (1956, p. 503 showed experimentally its application to the deformation of conglomerates. This hypothesis requires that the main flow in the rocks is parallel to fold axes and this is not accepted by many workers.

PSEUDO DEFORMED CONGLOMERATES

These rocks contain flat, elongate or somewhat irregularly shaped fragments in a foliated matrix and resemble deformed conglomerates very closely. They may result from the following processes:—

(1) Mechanical disruption (cataclasis) of various elements which were originally planar (beds, veins, dykes), cylindrical (mullions, quartz rods) or ellipsoidal (pebbles, boudins).

(2) Growth of ellipsoidal bodies, e.g. elongate, pebble-like blebs of quartz or pegmatite in schist (Quirke and Collins, 1930; Wilson, 1953; Reynolds, 1961).

(3) Accumulation of elongate clastic fragments under normal sedimentary conditions. Lineated quartzites commonly weather into cigar-shaped ellipsoidal fragments which might pack together to give a conglomerate with elongate fragments. With slight deformation a cleavage might be produced and the pebbles rotate to become parallel to the cleavage (Pettijohn, 1943; Glenn, Donner and West, 1957).

Pseudo-conglomerates produced by the first (tectonic) process above, have been found in regions where there are alternations of thin layers of differing competency. They are commonly associated with isoclinal folds in rocks which have been folded several times. The long- and mean-axes of the pseudo-pebbles are parallel to the foliation of the rock, and the long axes impart a lineation which is parallel to adjacent fold axes and other lineations. Such rocks are not uncommon and have been described by Paige (1924); Wegmann (1934); Engel (1949); Bailey and Tilley (1952); Sutton and Watson (1952); Wilson (1953, 1961); King and Rast (1956); Ramsay (1956); Back (1961); Baird (1962); Hills (1963); and Christensen (1963).

Pseudo-pebbles are a type of boudin. Pseudo deformed conglomerates have been called "boudinées" (Wegmann, 1934) and the deformation processes are related to boudinage. Two main genetic types of boudins may be recognized; the first is produced by non-rotational strain and could be called the *symmetrical type* (Ramberg, 1955) and the second is produced by rotational strain and could be called the *asymmetrical type* (Hills, 1940; Wilson, 1953; Rast, 1956; Baird, 1962; and Christensen, 1963).

The most common, simple, symmetrical boudins are sausage-like with one long axis, or barrel-shaped (Rast, 1956) or approximately equidimensional (chocolate-block). They are formed by the flow of less-competent past more-competent layers so that the more viscous or brittle layers are necked or ruptured to give lenticular, oval or blocky cross sections. Ramberg (1955) produced this kind of boudinage experimentally by flattening.

Many quartzite layers, quartz veins, quartzite fold-mullions and pebbles at Picnic Point and Goat Island have been fragmented by this process. They are characterized by orthorhombic symmetry of form, pointed ends, incompletely disrupted boudins, lines of closely spaced fragments of similar size, shape and composition, and by a foliation wrapping around the boudin. Some examples contain internal shears which are symmetrically developed as two sets at 40° to each other with the long axis of the boudin as the acute bisectrix.

Asymmetrical boudins formed by the intersection of compositional layering and a foliation are related to the cleavage mullions of Wilson (1953). Shearing takes place along the bounding surface of the mullions. Rotation of the cleavage mullions on the limbs of folds produce "lozenge-shaped" cleavage boudins (Rast, 1956). Baird (1962) showed that this process produced pseudo deformed conglomerates in the cores of folds where curved and intersecting near-axial fracture-cleavage sliced quartzite layers into pebble-like rods. All gradations from undissected folds to tectonic breccias with relict isolated fold hinges were found. Matley described similar rocks as long ago as 1899 and noted that the harder layers were drawn out into lenses, rolled into strings or broken into fragments.

Christensen (1963) showed the importance of bedding-cleavage intersections in producing lenticular layering which simulated flattened and stretched pebbles. The limbs of folds were disrupted by slip on closely spaced cleavage and the fragments were rotated to form lenticular fragments lying with their long and mean axes parallel to the cleavage, and their long axes parallel to the bedding-cleavage intersection. Cores of isoclinal folds were detached and rolled into cylinders.

These processes have all operated at Goat Island and Picnic Point. Quartzite layers and quartz veins have been sliced through by an oblique, penetrative foliation leaving lines of *en echelon* lenses resembling pebbles. Large fragments (some of which were probably boulders but some certainly detached fragments of beds) and fold mullions (with folded cores visible) have been sliced through by intersecting foliation surfaces. The smaller fragments are still in contact in many places but others are slightly or greatly displaced. These commonly have concave surfaces. Nested fragments and "tadpoles" are also commonly formed in this way and many thin wisps and flakes have been sliced off larger bodies.

GOAT ISLAND CONGLOMERATE

Abundant exposures of the rock known as "Goat Island Conglomerate" on the beach and wave-cut platform between Goat Island and Picnic Point (Burns, 1964) are composed of detached, rootless quartzite bodies of various shapes and sizes in a sparse, foliated quartz-mica (phyllite) or quartzose matrix. The quartzite bodies include many pebble-like or boulder-like objects which range from a centimetre or so to a metre in length, with the dimensions 30 x 15 x 7 cms. being common. Most fragments are composed of medium to fine-grained quartzite, mainly white but some pink or grey, some foliated and some massive. Grey flaky fragments of phyllite are common in some places.

The rock is monolithologic and a comprehensive search has failed to locate a range of rock types among the fragments; this would have established

the existence of primary conglomerate. True conglomerate is known from the Ulverstone Metamorphics at Spalford, 10 miles to the south (Burns, 1964), and conglomerate on the beach midway between Goat Island and Picnic Point is only very slightly deformed (Plate I). Much of the Goat Island rock was probably originally conglomerate.

The shapes of the fragments are not generally geometrically simple and it is difficult to classify them but the following twelve types are most common at Goat Island:—

1. Sub-spherical simple ellipsoids.
2. Simple triaxial ellipsoids—prolate (cigar-shaped).
3. Simple triaxial ellipsoids—oblate (plate-shaped).
4. Platy flakes or wisps.
5. Asymmetrical twisted ellipsoids.
6. Concave-convex ellipsoids.
7. Tadpole-shapes (asymmetrical ellipsoids with one rounded bulbous end and a sharp "tail").
8. Sub-quadrate ellipsoids.
9. Single-boudinaged ellipsoids (with one neck).
10. Multiple-boudinaged ellipsoids (with several necks).
11. Nested groups.
12. Irregular shapes which cannot be named.

This classification is somewhat arbitrary but some outcrops mid-way between Goat Island and Picnic Point are composed mainly of types 1 and 2; strongly deformed conglomerates at Goat Island contain abundant examples of types 2 to 8; pseudo deformed conglomerates from Picnic Point are rich in types 9 to 12.

At the Goat Island outcrop, the long axes of the parallel ellipsoidal fragments constitute a strong lineation which is parallel to fold axes in adjacent or enclosed phyllite and quartzite and to lineation (ribbing, mineral elongation) in quartzite. The mean and long axes of flat "pebbles" lie in the dominant foliation (S_3) which is subparallel to the axial surfaces of F_2 folds. Considerable departure from parallelism occurs and many pebbles are slightly oblique to the foliation. These are cut by "internal shears" which pass out into S_2 of the matrix and which range from one set of parallel planar surfaces to complex systems of curved surfaces intersecting the exterior of the fragments to give curved, crossing lineations. The internal shears make large angles with the short axes of the fragments. Movements which can be seen to have taken place parallel to the shears are always compatible with the apparent deformation of the fragments; displacements are usually very small but range up to almost a centimetre. The internal shear surfaces exposed on broken "pebbles" are commonly covered with a film of mica flakes and some show a fine lineation parallel to the visible displacement. Under the microscope the internal shears appear as zones of cataclasis and elongation of small recrystallized quartz grains or as intersecting lines of parallel mica flakes.

Petrofabric Analysis

Detailed petrofabric analysis of a variety of rocks from Goat Island to Picnic Point (presented elsewhere) shows that the quartz fabrics of quartzites, boudins, deformed pebbles and pseudo-pebbles are generally similar.

The main fabric-elements consist of a girdle of quartz [0001] normal to the long axis of pebbles and boudins and to the lineation of interbedded quartzites. A small-circle concentration with an axis perpendicular to the major foliation is most notable in the boudins where its axis is parallel to the shortest axis of the boudin. The girdle normal to the lineation is strongest in the quartzites.

Examination of petrofabric diagrams for quartz in deformed pebbles from other conglomerates by Strand (1945), Brace (1955), Flinn (1956) and Koark (1961) and in boudins by Delitsin (1964) suggests some features in common. Most important is the persistence of the plane of symmetry normal to the long axis of the pebble. The common lack of quartz optic axes near the long axis of the pebble may be expressed as a single strong girdle (Strand, 1945), as two girdles, symmetrically disposed about the long axis (Brace, 1955) or as a cleft girdle whose axis is the long axis of the pebble. The fabrics at Goat Island show all three tendencies. A general lack of optic axes near the mean pebble-axis causing a symmetrical break in the main girdle pattern is also seen in the diagrams of Strand. The tendency for optic axes to be concentrated near the short axis (with perhaps a broken small-circle near this axis) is also shown by Flinn.

In general, the Goat Island fragments have fabrics which are most similar to Flinn's Fetlar specimens. The degree of preferred orientation is not nearly as high as Brace's Vermont specimens in which no diagram contains a maximum weaker than 5%, with abundant 8% maxima and one of 16%. Maxima of 3, 4 and 5% are found in diagrams from Bygdin, Fetlar and Goat Island.

Neither Brace (*ibid*, p. 135) nor the authors have been able to find a correlation between the amount of deformation indicated by the form of the pebble and the degree of preferred orientation of the quartz optic axes. There is however a suggestion in the work of Flinn (figure 7 and p. 502) that the preferred orientation of quartz is stronger in more-strongly deformed pebbles.

DISTINGUISHING CHARACTERISTICS OF DEFORMED CONGLOMERATES AND PSEUDO DEFORMED CONGLOMERATES

Pseudo deformed conglomerates so closely resemble true deformed conglomerates as to be indistinguishable in certain instances. An observer who begins at the Picnic Point end of the exposure passes west across the strike from tightly folded quartzites and phyllites into the same rocks with detached and boudinaged beds, fold-mullions and quartz-veins, thence into pseudo deformed conglomerates in which the abundant lenticular quartzite fragments in a phyllite matrix have been produced by boudinage of interbedded thin quartzite and phyllite. Further west he passes into rocks which were probably originally conglomerates but which now contain abundant examples of boudinaged beds and veins and he might well conclude that no conglomerates are present at all. On the other hand if he began about mid-way between Goat Island and Picnic Point he would find slightly deformed rocks containing almost-spherical quartzite pebbles with smooth surfaces in a semi-pelite matrix. He could pass from these into rocks of

similar appearance in which the fragments are long or flat and conclude that the rocks are generally true deformed conglomerates.

A deformed conglomerate can only be recognized *with certainty* if it contains, in some sufficiently undeformed part, bodies which cannot be anything else but pebbles. Nearly-spherical bodies with smooth surfaces have apparently the only shape common in pebbles which is not produced by tectonic processes *in situ*, although in high grade metamorphics, tectonic inclusions take on a well rounded form.

A gradation from a comparatively undeformed condition may allow a deformed conglomerate to be recognized, or some feature may be locally diagnostic of pebbles (Hills, 1963, p. 124). A range of composition of pebbles is generally taken as strong evidence against a pseudo-conglomeratic origin.

A detailed study of the fabric of deformed pebbles and pebble-like tectonic inclusions at Goat Island has not revealed reliable criteria for distinguishing between them by petrofabric analysis.

The features which suggest a pseudo deformed conglomerate are—

(1) Fragments with shapes different from those known to be produced by deformation of clastic particles;
(2) A limited range of compositions e.g. quartzite fragments in phyllite matrix, granite fragments in mica schist, amphibolite fragments in greenschist;
(3) Arrested stages in the boudinaging of beds, veins, mullions &c.;
(4) Lines of closely spaced fragments of identical composition;
(5) Extreme irregularity and variety of shape and size of fragments;
(6) Fragments with extreme dimensions;
(7) Concave surfaces on fragments;
(8) Restrictions of the conglomeratic rock to certain tectonic positions;
(9) Lack of true conglomerate in undeformed equivalents.

Empirically, it seems that pseudo-stretched conglomerates are found only in rocks which have been isoclinally folded, especially those folded twice.

The application of these criteria to the rocks from Goat Island and Picnic Point indicate fairly conclusively that true deformed conglomerate is abundantly present but that a significant proportion of the "pebbles" are not simple deformed pebbles.

Boudinage is common in the interbedded quartzites and phyllites at Picnic Point (Plate I). The boudins are up to 10 metres long with pronounced thinning-down or pulling-apart at the necks with extension fractures filled by secretion quartz. Many layers are boudinaged sheets but some are boudinaged fold cores (Plate I, No. 5).

Some simple and sub-spherical ellipsoids appear to have been originally somewhat spherical bodies, i.e. pebbles and boulders (Plate I, Nos. 2, 3). The single- and multiple-boudinaged fragments are regarded as arrested stages in the formation of ellipsoids or tadpole shapes and have been formed from ellipsoids (pebbles), cylinders (fold mullions) and sheets (beds) by a simple boudinage process. The nested varieties, at least in some instances, were originally larger bodies (ellipsoids, cylinders, or sheets) which have been sliced into an aggregate of smaller bodies by curved and intersecting shear surfaces. These shear surfaces pass through the fragments ("internal shears"), and are expressed in the fabric. They are essentially parallel to, and continuous with, the foliation in the matrix of the rock. Most of the "flakes" or "wisps" are thin slices which have been removed from other fragments. Other ellipsoids appear to have been larger bodies which have been disrupted by the somewhat irregular injection of matrix and may be related to the boudins in the cores of folds described by Baird (1962).

Pseudo conglomerates at Picnic Point are recognizable where the disruption of the boudinaged quartzite layers has been arrested and the lenses are still just connected by thin necks. "Stretched" conglomerate is recognized by the presence, particularly in the central part of the area, of abundant, smooth, sub-spherical quartzite bodies which have the appearance of undeformed pebbles, impinge on each other with convex surfaces, have no linear arrangement in the matrix, or whose origin cannot be explained in terms of boudinage.

Once a rock has been moderately deformed however, it may not be possible to decide whether an individual fragment was once a pebble which has been simply elongated, or whether it was a pebble which has been singly or multiply boudinaged or is a boudinaged mullion.

This limits the use of pebbles as strain indicators. Deformed pebbles have been regarded as strain ellipsoids (Turner and Weiss, 1963, p. 389) and conclusions have been derived as to the kind, symmetry, or amount of strain of the region from a study of pebble shape. Quantitative evaluation of strain is unlikely to be valid in many regions because—

(1) Many deformed conglomerates are in structurally complex areas which have undergone several deformations;
(2) Practically all have an abundant matrix in which large amounts of unmeasureable strain has taken place;
(3) Some very oddly shaped fragments are probably pseudo-pebbles;
(4) Pebbles may undergo profound volume changes due to recrystallization, disruption such as pull-apart during boudinage or slicing off of corners.

CONCLUSION

Although many of the fragments in the Goat Island conglomerate were once pebbles there is evidence that the deformation was a cataclasis or disruption rather than a homogeneous deformation of closed bodies which retained their identity during deformation. There is also evidence that some of the fragments are not pebbles but are boudinaged and dismembered beds so that some rocks are, in fact, only pseudo deformed conglomerate, i.e., the *boudinée* of Wegmann (1934). Thus the metaconglomerate is an assemblage containing fragments of diverse origins; some are pebbles, some are boudinaged and dismembered pebbles, and some are boudinaged and dismembered beds.

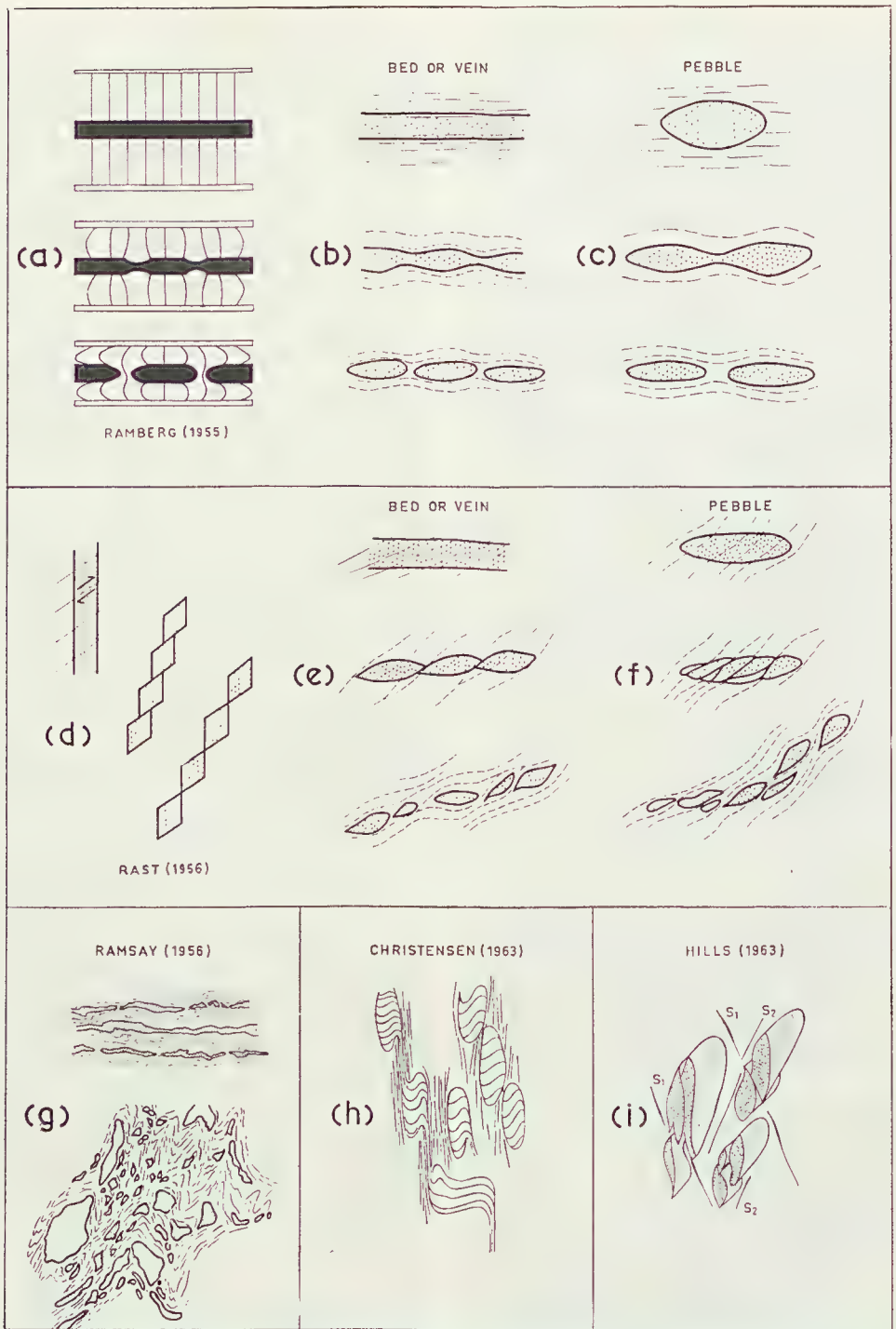
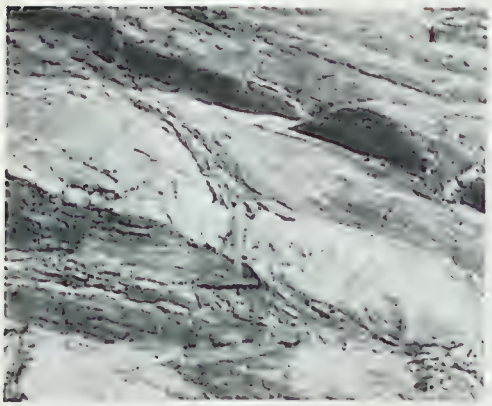


FIG. 1.—Boudinage mechanisms. (a) Experimental boudinage by pure shear after Ramberg (1955), (b) boudinage of a bed, (c) boudinage of a pebble, (d) boudinage produced by simple shear after Rast (1956), (e) boudinage of a bed or vein, (f) boudinage of a pebble, (g) Pseudo deformed conglomerate (Ramsay, 1956), (h) Disruption of layers in a fold-core to produce pseudo-pebbles (Chistensen, 1962). (i) Disruption of layers by movements on two shears, S_1 and S to produce pseudo-pebbles (Hills, 1963).



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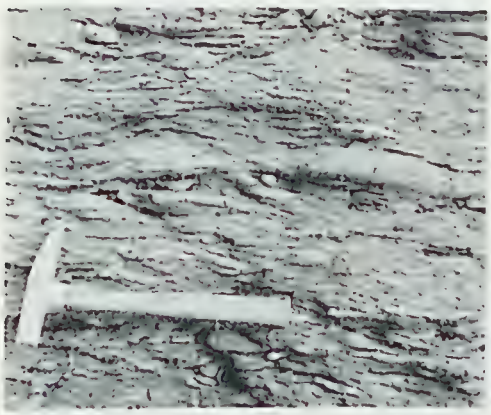

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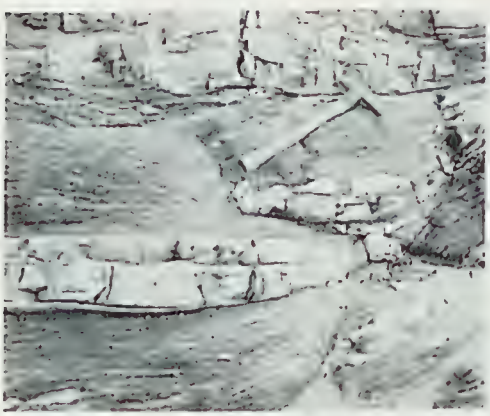

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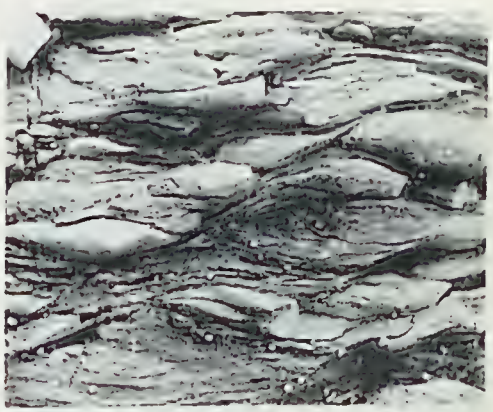

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PLATE I.—

No. 1.—Thick quartzite, Picnic Point. The foliation in enclosing phyllite is S_1 parallel to S_2. The boudin node is milky quartz.

No. 2.—Necked pebble, Picnic Point. A quartzite layer just above the fragment has been sliced into pebble-like fragments.

No. 3.—Boudinaged quartzite layer, strongly necked.

No. 4.—Isolated quartz lenses in phyllite due to disruption of a quartz vein.

No. 5.—Boudinaged isoclinal folds in quartzite, Picnic Point.

No. 6.—Pebbles disrupted at a shear surface crossing the foliation at a low angle.

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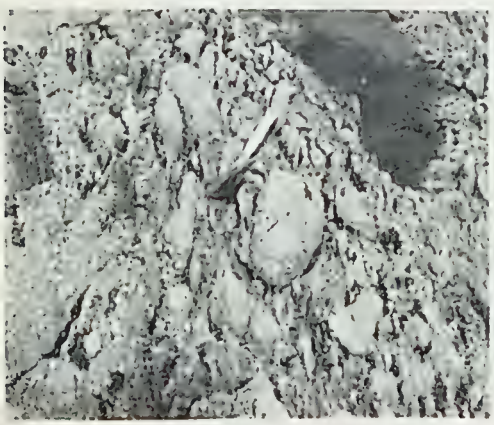

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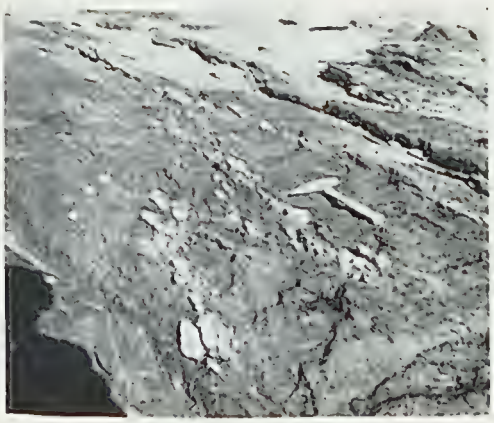

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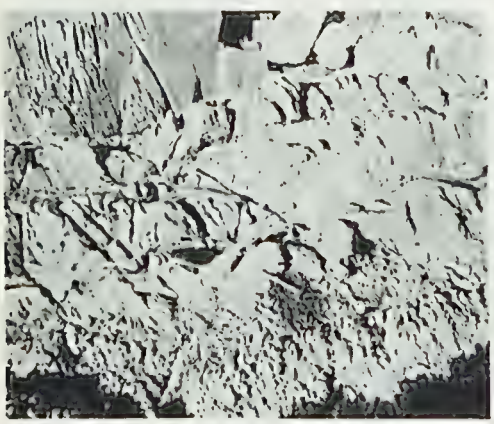

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PLATE II.—

No. 1.—Almost undeformed conglomerate, "central outcrop", (mid-way between Goat Island and Picnic Point), with subspherical boulders in a phyllite matrix.

No. 2.—Isolated, subspherical quartzite pebbles in phyllite matrix, central outcrop.

No. 3.—Mildly deformed conglomerate, central outcrop.

No. 4.—Folded pebbly layer in phyllite, eastern end of marine platform, Goat Island. The principal foliation in the phyllite, S_2 is axial-surface to the near-isoclinal folds.

No. 5.—Thick layers of quartz-rich phyllite overlying metaconglomerate, North-east Goat Island.

No. 6.—Metaconglomerate at Goat Island viewed along the lineation, with a layer of phyllite strongly transposed along the foliation.

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